CANADA
DEPARTMENT OF MINES
SIR JAMES LOUGHEED, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

MEMOIR 128



No. 109, GEOLOGICAL SERIES

# Winnipegosis and Upper Whitemouth River Areas, Manitoba

# Pleistocene and Recent Deposits

BY

W. A. Johnston

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1921

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in the valley of Mossy river, and agriculture was carried on prior to 1890, but the chief influx of settlers occurred during and subsequent to the construction in 1896-98 of the Canadian Northern (now Canadian National) railway from Dauphin to Winnipegosis and from Dauphin to Swan River, the latter line passing through the western part of the area. Prior to the

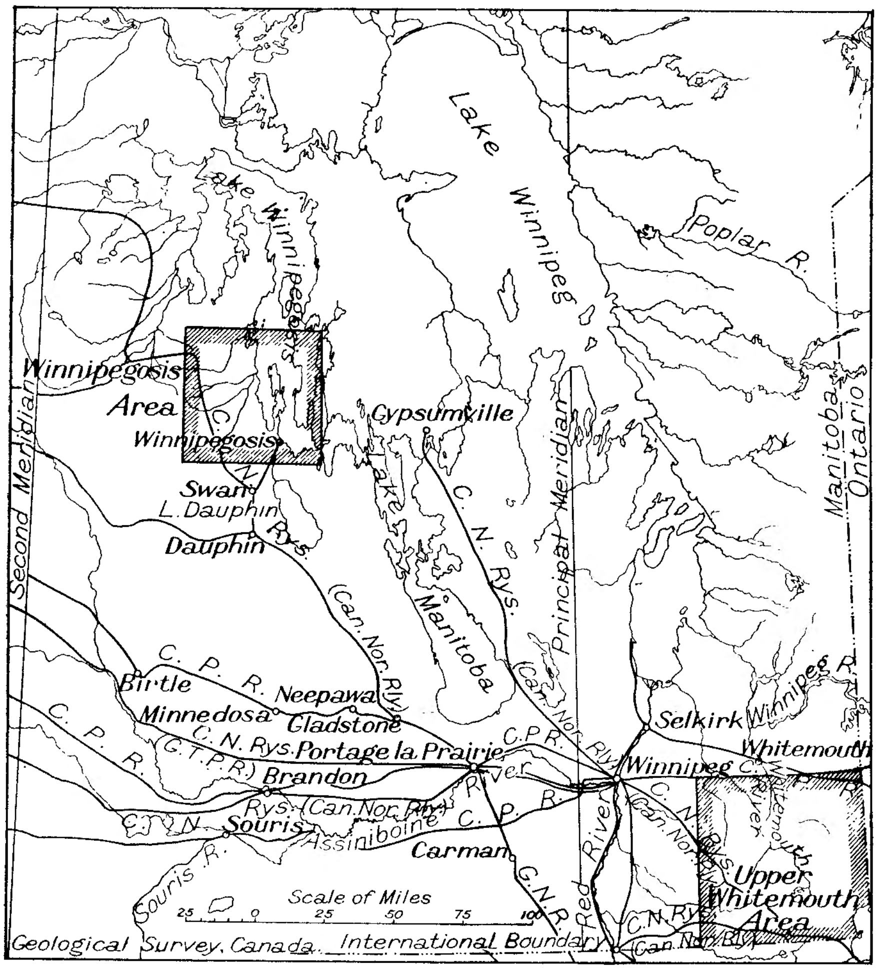


Figure 1. Index map showing the location of Winnipegosis and Upper Whitemouth River areas, Manitoba.

construction of this railway a colonization road which is paralleled by the railway afforded communication between Dauphin and Swan valley; but, after the construction, the road in the northwestern part of the area fell into disuse and at present is passable only as far as Cowan. The area around Winnipegosis is well supplied with roads. A road runs from

Winnipegosis north to Camperville at the Pine River Indian reserve on the west side of the lake, and west from Camperville to the railway at Cowan, and another road crosses the southern border of the area between the two railways; but the central parts of the area are poorly supplied with roads. Winnipegosis is the most important place in the area. It had a population in 1911 of 518, and is somewhat larger now. The total population, including Indians, of the whole area in 1901 was 1,958 and in 1911, 4,090. The Indians on the two reserves, Pine River and Waterhen, numbered 284 in 1901 and 312 in 1911. The land available for settlement is occupied chiefly in the southern parts near Winnipegosis and in the western parts along the Canadian National railway and along Pine river. No settlers are located in the northeastern parts except along Waterhen river; much of the Red Deer peninsula and the parts away from the lake are unoccupied by settlers. A number of small sawmills are located in the district, but lumbering was formerly of greater importance than it is at present. Several small forest reserves occur, chiefly on Red Deer peninsula, which is also a game preserve, and the area is bordered on the west by the large Duck Mountain forest reserve. Fishing, one of the most important industries of the district, gives employment, during the winter months, to a considerable number of the inhabitants. It is carried on by boats for a month during the open season in the autumn and through the ice during the winter months. Large quantities of fresh fish are shipped annually to Chicago and to other points. The lake is navigated by steamboats drawing about 6 feet of water.

## PREVIOUS WORK

A large part of northwest Manitoba, including the Winnipegosis area, was geologically examined and mapped (8 miles=1 inch) by J. B. Tyrrell and D. B. Dowling in 1887-90. Their report[1] is at present the standard authority on the geology of the region, and contains the chief references to the surface geology. The authors describe the Pleistocene deposits and mapped some of the raised beaches of glacial Lake Agassiz, barometer elevations of which were also obtained. These elevations and descriptions of the beaches were later used by Warren Upham in his description of the northern part of the basin of glacial Lake Agassiz.[2] Comparatively little geological work has been done in the area since the work by Tyrrell and Dowling. The salt springs of the area were in part investigated in 1913 by L. H. Cole[3] and by R. C. Wallace[4] in 1914. The raised beaches along the Canadian National railway were described and a general account of the geology of the region given in 1913 by A. Maclean.[5]

## TOPOGRAPHY

The area is part of the Manitoba lowland[6] and is bounded on the west by Duck mountain which rises 1,000 feet or more above the lowland and forms part of the Manitoba escarpment extending northwest through western Manitoba and rising in places to 2,500 feet above the sea. The

[1] "Report on northwestern Manitoba," Geol. Surv., Can., vol. V, pt. E, 1890-91.
[2] U.S. Geol. Surv., Mon. XXV, The glacial Lake Agassiz, 1896.
[3] "Report on the salt deposits of Canada and the salt industry," 1915; Mines Branch, Dept. of Mines, Can.
[4] Geol. Surv., Can., Sum. Rept., 1914, p. 73.
[5] Geol. Surv., Can., Guide Book No. 8, pt. III, 1913, p. 357.
[6] Dowling, D. B., "An outline of the physical geography of Canada," 13th Ann. Report, The Geog. Board of Canada.

escarpment or abrupt rise from the lowland is usually steepest in its upper part and has a fairly gentle slope in its lower part. It is interrupted in places by broad, gently sloping valleys which head well back on the upland and drain towards the northeast. One of the largest of these is Swan River valley, the beginning of the lowest part of which occurs in the northwestern corner of the area. It lies north of Duck mountain between it and Porcupine mountain. South of the area another broad valley extends west and lies between Duck and Riding mountains. The escarpment and broad valleys are mainly preglacial in origin, but are somewhat modified by erosion and deposition by the ice-sheet during the Pleistocene period immediately preceding the present period, and to a small extent by erosion and deposition by wave action and by streams since the disappearance of the ice-sheet. The escarpment was formed by the gradual eating back by stream erosion and weathering of the soft rocks which form its base. The rock formations dip gently towards the southwest. They formerly extended much farther northeastward and their surface slope was probably in the same direction. The broad valleys were formed by streams which headed on the upland or gradually ate their way back by headwater erosion and flowed towards the northeast. The present streams, in places, occupy the ancient valleys, but their courses are largely controlled by the mode of deposition and character of the drift deposits, and are, therefore, largely independent of the ancient drainage channels. The face of the escarpment is in many places trenched by narrow, steep-sided ravines partly cut in drift deposits and, therefore, in part post-glacial in origin.

The topography of the area, in respect to its smaller features and excepting its main physical features, as outlined above, is the result of erosion and deposition by the Pleistocene ice-sheets and post-glacial erosion and deposits. The extent of ice erosion in the area during the Pleistocene is not definitely known. The ice-sheets probably eroded material from the face of the escarpment and steepened it, and eroded the bedrock to some extent in the lowland area, but no rock basins are known. The ice-sheet probably modified the preglacial topography of the area chiefly by depositing drift materials. The drift conceals the bedrock over the greater part of the area and varies in thickness from a few feet to 100 feet or more, but in most places is less than 100 feet. It is thickest in the valleys, along the face of Duck mountain and on its summit, where immense accumulations of morainic material occur. The direction of nearly all the stream valleys almost throughout their length is controlled by the mode of deposition of the drift deposits, consisting in part of boulder clay and in part of lacustrine deposits. Long and narrow ridges of boulder clay, separated by swamps, are a marked feature of the topography of the lower parts of the area where the surface is boulder clay with little or no covering of lacustrine deposits. They are well shown in the northeast, are of low relief, and trend in the same general direction—a few degrees west of south—as the glacial striæ. Formed by the moulding action of the ice-sheet they have been only slightly modified by erosion or deposition since its disappearance.

The most striking topographical feature of the lacustrine deposits which occur chiefly in the western and southwestern parts is a series of long, narrow ridges trending northwest parallel to the front of Duck

mountain. These are beach ridges formed along the shores of an ancient lake which, following the melting back towards the north of the ice-sheet, covered the greater part of the area. The highest beaches occur on the face of Duck mountain and lower beaches, formed as the surface of the lake gradually fell, occur at lower levels on the lowland towards lake Winnipegosis. The beaches have the effect of diverting in places the stream drainage and act as dams behind which the water is ponded and swamps are formed. The lacustrine sands and silts deposited in the lake waters cover in places, chiefly in the southwestern parts of the area, the glacial till and form a nearly level, partly swampy, surface. Since the disappearance of the lake, the deposits have been somewhat dissected by streams; and swamp deposits due to the lack of natural drainage or to ponded waters have formed in the nearly level areas. Because of the recency, geologically, of the disappearance of the lake, comparatively little erosion of the drift deposits has taken place.

## RELIEF AND DRAINAGE

The lowest part of the area is in the basin of lake Manitoba, a small part of which is included in the southeastern corner. The lake has a mean altitude of about 814 feet above the sea and lake Winnipegosis about 831 feet.[1] The highest part of the area is along the face of Duck mountain. In the area mapped, the highest parts, in the southwestern corner, are about 1,350 feet above sea-level and in the northwestern part about 1,500 feet. A few miles west of the area the highest parts of the mountain—which is really an upland or plateau—are about 2,400 feet above the sea. The general relief in the lowland area is very small. The greater part of the area east of lake Winnipegosis is only a few feet above the level of the lake. In places the drift ridges and rocky knolls are 50 to 60 feet above the lake, but the highest point is probably less than 100 feet and many of the ridges are only 20 to 30 feet above the lake, and the intervening swamps are somewhat lower. Many of the swamps are continuous for long distances and in part occupy natural, undrained basins in the drift deposits. Small undrained depressions are a feature of the surface of the glacial drift. The swamps which occupy the depressions in the northeast are difficult to drain because they, in part, occupy basins without natural outlets and have very slight surface slopes. The slight natural drainage is towards the northeast.

The whole of the Red Deer peninsula and the parts of the area bordering the south and west sides of lake Winnipegosis for several miles back are of very low relief. The highest parts of the peninsula are only about 30 feet above the lake. South and west of the lake for 8 to 10 miles the highest parts are only 50 to 100 feet higher, and the local relief between the drift ridges and adjacent swamps is only about 10 feet. The surface rises gradually westward toward Duck mountain, the rise being more rapid the closer to the mountain. Along the southern border of the area there is a fall of 260 feet from the railway at Ethelbert to the railway running to Winnipegosis, or at the rate of 15 feet to the mile. The rate of fall is fairly uniform but is somewhat greater near Ethelbert. In the northwest the slope eastward along the road from Cowan on the railway to Camperville on lake Winnipegosis is

[1]White, James, "Dictionary of altitudes in Canada," Commission of Conservation, Ottawa, 1916.

also about 15 feet per mile. West of the railway the surface slope is somewhat greater for 4 to 6 miles to where the steep slope of the escarpment begins. The local relief is usually only 10 to 20 feet throughout the area east of the railway. Along the railway and west of it the relief is greater and in places the streams have cut ravines 50 to 100 feet deep and low hills and cliffs rise to about the same heights.

Lakes Winnipegosis and Waterhen occupy considerable parts of the area and numerous small lakes and ponds occur in its eastern half. The lakes occupy natural depressions in the drift deposits and a few of the smaller ones have no natural outlets. The lakes are due to the irregular deposition of the drift deposits and because there has been insufficient time to cut outlet channels. Lake Winnipegosis could be largely drained by a channel through the narrow neck of glacial drift that separates it from lake Manitoba at Meadow portage. Lake Manitoba is about 17 feet lower and a large part of lake Winnipegosis, as shown by soundings made by Tyrrell and Dowling, is less than 17 feet deep. It is said to be about 45 feet in the wide part north of Red Deer point, and somewhat deeper in a few places near the north end.

Lake Winnipegosis, because of its great length (over 100 miles) and its shallowness and narrowness in places, is markedly affected by wind-induced currents. Its surface at Winnipegosis has been known to rise as much as 3 feet during long-continued storms from the north or northwest, and frequently oscillates in level as much as 6 inches to 1 foot. It also varies in height from 1 to $2\frac{1}{2}$ feet according to the rainfall. Boulder beaches or "ramparts," composed largely of closely packed boulders too large to be moved by storm waves, are almost continuous along the shore. Tyrrell[1] concluded from the evidence of the tracks and grooves left by ice-shoved boulders that they are caused by the irregular pressure of wind-driven ice fields floating in the lake in the spring, rather than by the regular expansion of the ice during the winter, although the latter explanation for similar occurrences in other regions has been generally accepted. Exceptionally strong wind-induced currents, and, probably also, currents caused by differences of barometric pressure in different parts of the lake basin are points that favour Tyrrell's view. The present writer observed the track of an ice-shoved boulder that had been moved out of a bay and away from the shore—which also confirms Tyrrell's view. The fact, however, that boulder walls occur around the shores of many of the lakes which are too small to be affected by currents shows that the ridges are formed in part by the expansion of the ice during the winter. The area is particularly favourable for the formation of boulder beaches; for the material forming the shores of the lake is largely boulder clay and the shores are gently sloping. The fine material is gradually washed away, leaving, in the shallow water near the shore, the boulders which are moved shoreward by the expansion of the ice with a rise in temperature. When the ice contracts because of a lowering of the temperature it does not pull away from the shores but cracks, and open leads form, which are soon filled with new ice. Whether this action takes place to any great extent in lake Winnipegosis during the winter is not certain. It is well known to the inhabitants of the area that pressure ridges and open leads in the ice occur annually at certain places in the lake, but these, because of their magnitude,

[1] Ibid. p. 64 E.

are probably due chiefly to currents in the lake. It is probable, therefore, that the boulder beaches are formed chiefly by wind-driven ice fields at the time of the break-up of the ice in the spring as was held by Tyrrell, and partly by expansion and contraction of the ice and possibly also because of currents causing ice-pressure on the shores during the winter and early spring.

The most important streams are the Little Waterhen and West Waterhen rivers which flow north from the south end of lake Winnipegosis into Waterhen lake, and Mossy river flowing north from Dauphin lake to lake Winnipegosis. The fall from lake Winnipegosis to Waterhen lake is only about 2 feet. Waterhen river flows south from Waterhen lake to lake Winnipegosis with a fall of about 15 feet. Mossy river is 100 to 200 feet wide and 2 to 6 feet deep. It flows in a well-defined valley and does not overflow its banks. It falls 77 feet from Dauphin lake to lake Winnipegosis, the average rate being 3·5 feet per mile. The rate of fall varies and in places, notably 2½ miles above its mouth, rapids caused by accumulations of boulders occur. Numerous tributaries of lake Winnipegosis rise, for the most part, in Duck mountain, the most important being Duck and Pine rivers. Other smaller streams head on the lowland. The streams heading in Duck mountain have fairly deep, sharply-defined valleys in their upper parts as far east as the railway, and in the lower parts have low banks but little above the flood level. Their average rate of fall in the lowland east of the railway is 10 to 15 feet a mile, but in the lowest parts of their courses for several miles from the lake it is considerably less. The lower parts of Duck and Sclater rivers are practically at the level of the lake for 8 miles from their mouths. The level of the lake extends up Pine river for about 1½ miles and above this point for several miles the fall is only a few inches to the mile.

## VEGETATION

A large part of the area is clothed with dense arboreal vegetation, the growth of which is favoured, in spite of the comparatively small rainfall, by the nearness to the surface of the groundwater-level and by protection from extensive forest fires afforded by the numerous wet swamps and marshes. The forest growth, however, consists mostly of young, small trees except in the few areas that are forest reserves.

The most abundant forest tree is the aspen poplar which occurs along with balsam poplar and occasional trees of white spruce and balsam fir chiefly in the clayey, naturally-drained areas. The sandy and rocky ridges are generally marked by groves of jackpine and white birch. The poorly-drained parts, which constitute a large proportion of the area, are clothed chiefly with tamarack and black spruce. The deeper bogs are sparsely timbered with stunted tamarack or are treeless, quaking bogs and in places extensive marshes covered with wild grasses and water-loving plants occur. Elm, oak, and Manitoba maple occur sparingly in the better-drained areas and most commonly along the shores of lake Winnipegosis. Wild fruits such as the strawberry, high-bush cranberry, choke-cherry, etc., are abundant. Considerable parts of the area, burnt over at different times, are now occupied by brulé or by a young growth of small aspen poplar and other trees. Alder and willow occur abundantly around the borders of the swamps and marshes and along many of the streams.

## CLIMATE

Few climatic records are available for the area itself, but from records of observations for fifteen years at Dauphin 25 miles south and for ten years at Swan river northwest of the area the average climatic conditions may be estimated.

The climate is continental in character, that is, it is characterized by greater temperature extremes and less humidity and rainfall than that of regions near the coast. The winters are cold and the summers are warm. The precipitation is less than that of the Great Lakes region, but greater than that of much of the southern part of the Great Plains region in western Canada. The successful growth of crops for over thirty years shows that the area is climatically well suited for the growth and maturing of most of the ordinary farm crops common to the temperate zone. Lake Winnipegosis, which has a maximum summer temperature of about 70 degrees F., lessens the danger of summer frosts. The severe frost of July 25, 1918, which affected large areas in the northern parts of Manitoba, Saskatchewan, and Alberta, did no damage in the vicinity of the lake, but injured crops in the highland parts of the area and in Swan River valley.

The mean annual temperature at Dauphin is 34·6 degrees and at Swan River about 32 degrees. The mean annual temperature at Winnipeg is 36·2 degrees. The mean temperature of the growing months (May-September) at Dauphin is 57·6 degrees and at Swan River about 54 degrees. At Winnipeg, it is 60·0 degrees. The mean temperature of the principal growing months (June-August) at Dauphin is 62·7 degrees and at Winnipeg 64·4 degrees. January is the coldest month and July the warmest. Severe summer frosts have been known to occur, notably on July 25, 1918, when 5 degrees of frost were registered at Swan River, the lowest at Dauphin, however, being 1 degree above freezing point, but such occurrences are very rare. The average length of the growing season free from killing frosts is about 95 days, but varies greatly from year to year. The crops near the foot of Duck mountain have a shorter freedom from killing frosts, and because of altitude and distance from the lake, are more likely to be affected by summer frosts than are the crops near lake Winnipegosis.

The annual average precipitation at Dauphin is about 21 inches or nearly the same as at Winnipeg. At Swan River it is probably slightly less, but the amount is not definitely known. This is small as compared with the Great Lakes region, but nearly 70 per cent of the total precipitation comes in the growing season when it is most required and is well distributed. The average precipitation at Dauphin, for May to September, is 12·97 inches.

The snowfall varies greatly, but usually does not exceed 40 inches. The average is not definitely known. Nearly all the precipitation in the winter is in the form of snow, and thaws rarely occur.

## GEOLOGY

Bedrock in the area consists, as shown by Tyrrell, of limestone of Devonian age and sandstone, shale, and impure limestone of Cretaceous age. The Devonian limestone underlies the greater part of the lowland, and Cretaceous rocks form the escarpment of Duck mountain and lower slopes in the western part of the area.

The bedrock is overlain and largely concealed by superficial deposits of Pleistocene and Recent ages. The Pleistocene deposits consist in part of glacial drift and in part of lacustrine deposits formed in glacial lakes. During Pleistocene time, immediately preceding the Recent period, great ice-sheets or continental glaciers advanced from the north across the region and transported large quantities of boulders, sand, and silt. When the ice melted it left the surface covered with accumulations of these transported materials, the glacial drift. Near the close of Pleistocene time when the ice-sheet began to melt back towards the north, the drainage of the Manitoba lowland area was ponded between the retreating ice-front and the highland to the south and a great lake, known as glacial Lake Agassiz, came into existence. The lake was named and described by Warren Upham who examined the southern part of the lake basin in the state of Minnesota and in western Manitoba as far north as the latitude of Gladstone, some distance south of the Winnipegosis area. He showed that for a time the lake drained south into Mississippi river; that, during the time of southward outflow a series of beaches at successively lower levels were formed because of cutting down of the outlet and because of uplift of the land; and that during a later period it drained towards the north or northeast. During the later period a series of successively lower beaches were formed because of tilt of the land and because of the opening of successively lower outlets towards the north and northeast. He also showed that a considerable part of the uplift of the region was accomplished during the existence of the lake and held that the southern parts of the lake basin were affected by uplift before the northern parts. Tyrrell showed that some of the highest beaches of the lake occur on the east side of Duck mountain, where the rate of uplift was greater than in the more southerly parts of the lake basin. He also found beaches at higher altitudes in the Duck Mountain area than in the Porcupine Mountain area. The lake had two important stages separated by an interval during which it was partly drained and was again raised to the level of the southern outlet, probably because of a retreat and re-advance of the ice-sheet. As some of the beaches of the early stage occur along the east slope of Duck mountain but do not occur on the north slope, the ice-sheet must have rested against the north slope when the lake was in its early stage. The beaches of the second stage extend far beyond Porcupine mountain. The large moraine along the north side of lake Winnipegosis marks, probably, the ice-border during the early part of the second stage.

Altitudes of the beaches in the Winnipegosis area and at other points in northwestern Manitoba show that the late glacial and post-glacial uplift in the region was remarkably complex.

The deposits of glacial Lake Agassiz consist of sand and gravel beaches formed at various altitudes along the receding shores of the lake, and of sand, silt, and clay deposited in the bed of the lake.

The Recent deposits consist of alluvial, flood-plain deposits of the present streams, wind-blown sand, and swamp and pond deposits of muck and peat.

## PLEISTOCENE DEPOSITS

### GLACIAL TILL

Glacial till, or boulder clay, the unstratified deposit of the ice-sheet, underlies the greater part of the area and forms the greater part of the drift deposits. It was deposited chiefly as ground moraine formed beneath the ice-sheet or left on the surface after the melting of the ice. It is markedly calcareous and clayey because the ice-sheet advanced over limestone and shales. The till varies in thickness and in places is 50 to 100 feet thick, but as comparatively few borings have been made, the average thickness is not known. The surface of the till is of low relief and in places is nearly level. In most places low ridges 10 to 20 feet high, trending a few degrees west of south, are the characteristic feature of the till areas. The ridges are too imperfectly formed to be called drumlins, except possibly in the case of a few islands in lake Winnipegosis, notably those in the southern part of Sagemace bay. They are apparently due to the moulding action of the ice-sheet.

No definite evidence of more than one till sheet was found. Some of the valleys near Duck mountain, notably 1½ miles west of Sclater, contain horizontally-bedded sand and silt overlain and underlain by till, but the stratified deposits were, probably, formed in a glacial lake—possibly an early stage of Lake Agassiz—held in between the margin of the ice-sheet and the mountain on the west, and the overlying till was perhaps the result of a slight re-advance of the ice.

Fluvioglacial deposits of sand and gravel are practically absent, probably because the ice-sheet during its retreat was bordered by a lake, and the materials derived from the ice-sheet and deposited in the lake were mostly silts and clays.

### TERMINAL MORAINES

Terminal moraines, formed by deposition of material from the ice-sheet at its margin and marking stages of halt in its retreat, occur chiefly along the foot of Duck mountain and on its slopes. They consist of boulder clay which is as a rule more stony than the till of the ground moraine and they have a more marked surface relief. The great accumulations of morainic material on Duck mountain are due, probably, to its resistance to the advance of the ice. The direction of ice-movement as shown by the glacial striæ in the lowland area was nearly south. The general direction of glaciation, however, was southwest and the ice must have been thick enough at the time of maximum glaciation to override Duck mountain; for limestone drift was transported from the lowland to the summit. The striæ in the lowland area probably belong to the latest stages of glaciation when the ice-sheet was smaller and was diverted towards the south by the northeastward-facing mountain front.

The moraine along the foot of Duck mountain must have been formed by the continental ice-sheet and not by local glaciers on the mountain, for

the material of the moraine was largely derived from the lowland. It is possible that a local snowfield and small glaciers existed on the mountain, during and following the retreat of the main ice-sheet, and the fact that the beaches of the early stage of Lake Agassiz are well developed in places along the front of Duck mountain, but in other places are absent, seems to bear this out. The moraine shows that in this area Lake Agassiz at first covered a narrow strip only between the ice-front and the mountain, and grew in size as the ice melted back. The moraine near Cowan and those along the north side of Duck mountain appear to mark the position of the ice-front at a somewhat later stage, but no moraine extends across the lowland in the basin of lake Winnipegosis except at its northern end, apparently indicating that the ice retreated comparatively rapidly. The large moraine along the north side of lake Winnipegosis shows that the ice-sheet must have again halted for a comparatively long time during the general retreat, or re-advanced after the retreat. It probably marks the farthest advance of the ice-front during the second stage of the lake.

### GLACIAL LAKE AGASSIZ DEPOSITS

The stratified deposits formed in the bed of Lake Agassiz are widespread in the western part of the Winnipegosis area, but have in most places no great thickness. They are not abundant, partly because the lake fell gradually and the fine materials were washed down into the lowest parts of the area, and partly because there was no large supply; for though the lake during the second stage covered most of the area for a long time, the materials derived from the melting ice were scant, because it lay far to the north. During the early stage the ice appears to have covered most of the area. The lacustrine deposits were largely derived by stream erosion of land areas and are distributed mainly along the valleys of the streams flowing from Duck mountain along Mossy river.

The areas mapped as lacustrine sand and silt include some alluvial flood-plain deposits of the present streams. These deposits are probably thickest in the valley of Mossy river, which, although it does not overflow its banks at present, has done so in the past. They are usually darker than the lacustrine deposits because of the inclusion of organic matter and contain in places freshwater shells and other organic remains. They occupy comparatively narrow strips along the streams.

Numerous beaches of Lake Agassiz, chiefly in the west, occur at various altitudes from a few feet above lake Winnipegosis up to 1,490 feet on the east slope of Duck mountain. The beaches are relatively long and narrow ridges usually 6 to 15 feet high and 100 to 600 feet wide. In places, where the original slope was somewhat abrupt, wave-cut terraces occur, but wave-built barrier beaches or off-shore bars, such as are characteristically built on gently sloping shores, are the dominant features marking the ancient shore lines. The beaches occur at successively lower altitudes because the surface of the lake fell gradually or spasmodically owing to differential uplift of the land and to the opening of successively lower outlets of the lake. Two of the beaches, remarkably well developed, persist for long distances. The railway runs for 30 miles on the lower of these, from Ethelbert to Sclater. The higher and stronger beach, upon which an old Indian trail and the colonization road to Swan River were located, lies a short distance west of the railway, and is continuous from

near Ethelbert to beyond Pine River, where a wave-cut terrace begins, and extends north for several miles. Near Cowan it is again a wave-built beach and the railway is located on it. These two beaches are probably the Upper and Lower Campbell beaches as named and described by Upham, for they have been traced fairly definitely south to Arden, where they were mapped and levelled by him.

The beaches above the Upper Campbell beach are well developed in places but are discontinuous and difficult to trace. They belong to the early stage of the lake and do not occur along the north side of Duck mountain, but terminate near Cowan. The Upper Campbell beach, however, extends northwest into Swan River valley and probably as far northwest as the Pasquia hills. Its great strength shows that the waters of the lake must have persisted at the level of the beach for a long time, and the fact that it is a single strong beach as far north as it has been traced shows that uplift was not taking place when it was being formed. It probably marks the upper limit of the second stage of the lake.

The beaches below the Campbell beaches are not so well developed and are difficult to trace except in the south. Probably all the beaches of the lake except a few of the highest and those confined to the Winnipeg basin are represented in the area. The two lowest appear to be the Burnside and Ossawa beaches of Upham. There is also a raised beach, confined to the Lake Winnipegosis basin, which coincides with the present beach in its southern part. In the northern parts of the area it is 6 to 10 feet above the lake and at the north end of the lake 25 to 30 feet above. It is well shown at Duck bay, where beach ridges a few feet above the lake are overgrown with trees.

## LATE PLEISTOCENE CHANGES OF LEVEL

The character and extent of the changes of level during the existence of Lake Agassiz and following its disappearance may be in part determined by comparing the various altitudes of the same beaches, and their altitudes in the area with their altitudes at the southern outlet of the lake. The beaches were originally horizontal, but have been tilted or upwarped towards the north and northeast because of uplift of the land.

The Upper and Lower Campbell beaches were levelled at many points along the railway between Ethelbert and Cowan, and other beaches at different places. The upper beach, $1\frac{1}{2}$ miles west of Ethelbert, is 1,161 feet above the sea and the lower beach at Ethelbert 1,129 feet. At Cowan the upper beach is 1,205 feet and the lower, at a point $2\frac{1}{2}$ miles south of Cowan, 1,165 feet. The beaches are separated by a vertical interval which increases slightly in the northern part of the area. Uplift took place, therefore, to a slight extent while the surface of the lake fell from the level of the upper beach to the lower. The next lower beach also shows a slight amount of divergence. The rate of tilt of the upper beach, north 30 degrees east, which is probably about the direction of maximum uplift in the area, is 2 feet to the mile. The rate of tilt of the two beaches is nearly uniform for the whole distance. Tilting of a block of the earth's crust is, therefore, suggested rather than warping, but warping also occurred in the northern parts of the area. The altitude of the Upper Campbell beach at the southern outlet of the lake is 990 feet.[1] The area in the vicinity of Cowan

[1]U.S. Geol. Surv., Mon. XXV, 1896, p. 476.

has, therefore, been uplifted, since the formation of the beach, at least 215 feet.

The highest beach of the lake in the Winnipegosis area occurs 4 miles west of Cowan and has an altitude of 1,490 feet. It is not known to which beach in the southern part of the lake basin it corresponds, but it is probably one of the highest. As the highest beach at the southern outlet of the lake has an altitude of 1,055 feet the uplift in the vicinity of Cowan since the formation of the highest beach is at least 445 feet, if ice attraction in raising the level of the lake at the north end be neglected. Ice attraction may have had some slight effect during the early stage, but could have had little or none during the later stage, for the ice-sheet was much smaller and was far removed to the north. The greater amount of uplift of the highest beach than of the Upper Campbell beach shows that uplift took place during the early stage of the lake which existed previously to the formation of the Upper Campbell beach, or following its partial disappearance and amounted, near Cowan, to at least 230 feet.

The lowest Lake Agassiz beach in the area is probably the Ossawa beach. It is the first well-developed beach above lake Winnipegosis. It has an altitude of 894 feet, 2½ miles west of the railway from Dauphin to Winnipegosis, and, 8 miles farther north, has an altitude of 910 feet. It is not continuous as a beach ridge except in the south and, therefore, is difficult to trace; but as the only other beaches below it are very faint ones in the southern part of the lake basin, it can be identified in the northern parts of the lake basin. It has an altitude of 896 feet, 2 miles north of Brabant point and 1 mile inland on the east side of lake Winnipegosis, and at the north end of the lake has an altitude of 896-900 feet. Therefore, it probably has about the same rate of tilt, in the southern part of the lake basin, as the Upper Campbell beach, but is nearly horizontal in the northern part of the lake basin. The total uplift, as shown by a comparison of the altitude of the beach in the southern part of the area with its altitude at the southern outlet of the lake, is about 100 feet.[1]

A raised beach in the northern part of the Lake Winnipegosis basin is confined to the basin. Near the south end of the lake it coincides with the present shore line, but gradually rises towards the north and at the north end of the lake is 25 to 30 feet above the level of the lake. The lake has persisted ever since Lake Agassiz fell below the level of the outlet of the Winnipegosis Lake basin. The deformation of the raised beach shows that the differential uplift of the lake basin, in a northerly direction, is about 25 feet. The deformation of the beach, however, does not indicate the amount of total uplift which has taken place since the formation of the beach, for the outlet of the lake is near the south end and uplift may have affected the whole area without affecting to any great extent the level of the lake. Since the altitudes of the lowest Lake Agassiz beach in the area show that the southern part of the area was uplifted about 100 feet after the Ossawa beach was formed, a part of the uplift must have taken place after the disappearance of the lake. It seems also that the deformation of the Winnipegosis beach does not indicate the whole amount of uplift. The uplift, therefore, which affected the Winnipegosis area after

[1]Ibid, p. 476.

the formation of the highest Lake Agassiz beach was not continuous, but occurred mainly in two periods, one during the existence and following the partial disappearance of the early stage of the lake and the other during the existence of the second stage of the lake and following its disappearance. The two periods were separated by a period of comparative stability, during which the remarkably strong Campbell beaches were formed. About half the total uplift took place during the first period and about half the remainder during the existence of the second stage. The uplift of the first period affected the southern and western parts of the Winnipegosis area, but whether it affected the northern parts is not known, for the higher beaches do not occur in this area. The uplift of the early part of the second period affected the southern parts of the Lake Winnipegosis basin to a greater extent than the northern parts. The uplift of the latter part of the second period affected the northern parts of the lake basin to a somewhat greater extent than the southern parts. The evidence, therefore, confirms Upham's conclusion that the uplift proceeded from south to north, or that the southern parts of the lake basin were uplifted earlier than the northern parts.[1] A remarkable feature of the uplift is that the lowest Lake Agassiz beach is apparently slightly higher in the southern part of the lake basin than it is at the north end of the lake, although the Winnipegosis beach is definitely upwarped towards the north. It is possible that depression as well as uplift of parts of the area has taken place, but the beaches furnish little evidence in this connexion. The rate of uplift except in the northern part of Lake Winnipegosis basin is also greater than in the southern part of the Lake Agassiz basin and suggests that a hinge-line of uplift occurs south of the area.

## RECENT DEPOSITS

Alluvial deposits of sand and silt, formed on the flood-plains of the present streams, occupy narrow strips along Mossy and Duck rivers and are characterized by an abundance of organic matter.

Wind-blown sand occurs in a few places only in the northwest. The areas are in part old dunes which are partly forested and are not at present drifting sands. They occur near the ancient beaches from which the sand was derived.

The swamps and marshes contain deposits of peat mosses whose fibrous nature and vegetable origin are usually quite apparent. The peaty material is only slightly altered, because water-level in the swamps oscillates very slightly, the ground-ice persists until late in the spring or early summer, and the swamp waters are cold throughout the summer, giving little opportunity for oxidation of the material.

[1] Ibid, p. 486.

# ECONOMIC GEOLOGY

## SOILS

The soils are practically all drift soils, that is, they are derived from superficial deposits of Pleistocene and Recent ages. Their general character and mode of origin have been described (pages 10-14). The soil differs from the deposits upon which it is developed in that it has been affected by weathering; by the gradual accumulation in this stratum of animal and vegetable matter; and has been acted upon by life in some form, so that it is productive.

On the map (No. 1771) the distribution of the soils is shown by colours. The descriptive names, e.g., clay, loam, refer to the surface soil to an average depth of about 6 inches and are based on the texture or relative proportions of the different-sized constituent particles. Only the most characteristic soils are shown on the map, and the boundaries are approximate.

The soils, with the exception of the swamp soils, have been derived from glacial till and glacial-lake deposits. As these are calcareous, the soils as a whole are also calcareous, especially in their subsoil portions; but even the surface soil is only partly leached of its calcareous content. The till soils are the most highly calcareous; the swamp soils are not markedly acid, except where saline or mineral springs occur, due to the abundance of limestone in the under soils.

The soils have the light to medium dark colours of the soils of most timbered regions and lack the deep black characteristic of the prairie soils. The swamp soils are mostly brown. The æolian, beach, and lacustrine fine sand soils are usually light-coloured, indicating a low organic matter content. The till soils are brown to black and are for the most part well supplied with organic matter.

The "lightest" soils of the area are the æolian and beach sand soils. They occupy comparatively small areas and on account of the relief of the surface and porous character of the materials are easily affected by drought in dry seasons. The "heaviest" soils are the till soils, which occupy the greater part of the area. The lacustrine fine sand and sandy loam soils are intermediate between the light and heavy soils.

The total land area mapped is 1,418 square miles of which about 2 are bedrock outcrop and 524 are swamps. The following table gives the areal distribution of the soils exclusive of those portions occupied by swamps and outcrops.

| | Square miles |
|---|---|
| Æolian soils— | |
| Dune sand | 5 |
| Beach soils— | |
| Gravelly sand and coarse sand | 28 |
| Lacustrine soils— | |
| Fine sand and sandy loam | 145 |
| Glacial till soils— | |
| Clay loam and clay | 694 |
| Stony clay | 20 |
| Total area | 892 |

### *Swamp Soils*

*Muck and Peat.* The organic deposits which occupy the surface in the swampy areas are not true soils, because they consist almost entirely of organic matter, but must be regarded as the soil in places where they

are over 1 or 2 feet thick. The muck contains a greater amount of mineral soil than the peat and the organic material which comprises a considerable part of it is more decomposed. It is, therefore, more nearly a true soil than the peat. The muck areas are small and occur in a few places along the streams where mineral soil has been included in the peaty material by overflow of the stream.

The formation and preservation of the organic deposits are due to the nearness to the surface of the groundwater-level; and as there is little oscillation of the water-level and the swamp waters are cold, very little atmospheric oxidation or alteration of the material has taken place. Practically the only mineral matter in the swamp deposits is derived from the ash of the plants. The peaty material is, therefore, deficient in some of the elements necessary for the growth of plant life, particularly potassium. It contains a large amount of nitrogen, an essential for the growth of plants, but the nitrogen in peat is largely in a form not available for plants, and to render it available it is necessary to convert the peat, at least in part, into humus. This is partly accomplished by drainage, cultivation, and æration. Drainage, by lowering the water-level, induces atmospheric oxidation and decomposition of the peat and produces a mucky soil. In areas covered by 1 to 3 feet of peaty material, the peat largely disappears after drainage and cultivation, for the bulk of it is reduced by oxidation and when mixed with the undersoil forms a rich, mucky soil. Where the peat is thick it is of low agricultural value; fertilizers and lime are needed to correct its generally acid character and render it productive.

The swamp soils of the Winnipegosis area are not markedly acid, except in the areas along the south and west sides of lake Winnipegosis and on Red Deer peninsula, where saline or mineral springs occur. The abundance of limestone in the undersoil renders the swamp waters somewhat clear and helps to correct the acidity of the swamp deposits. Natural drainage is very deficient, partly because of the low relief, but chiefly, in the west, owing to the numerous beach ridges of sand and gravel, which act as dams. The natural slopes west of the lake would be sufficient if obstructions to the natural drainage were removed and if it were supplemented by artificial drainage. The comparatively small precipitation also favours the drainage of the swamps.

The areas mapped as hay marsh are covered with marsh grasses and water-loving plants. They form in part natural hay meadows, but are also in part wet bogs, and in part salt marshes, barren or nearly barren of vegetation.

### *Æolian Soils*

*Dune Sand.* Dune sand occurs in small areas, chiefly in the northwest. The soils are of little agricultural value, chiefly because if cultivation is attempted, the sand is likely to drift. The areas are partly forested with a sparse growth of jackpine and the sand is not at present drifting to any great extent.

### *Beach Soils*

*Gravelly Sand and Coarse Sand.* The surface soil consists of white to yellowish-brown sand and in places coarse sand containing a varying proportion of gravel. The subsoil consists of lighter-coloured sand with gravel. The soil in most places has a low content of organic matter or humus.

The beach soils occupy small areas, chiefly in the west. The surface is in the form of low and relatively long, narrow ridges. Because of the relief of the surface, and the porous character of the material the soil is easily affected by drought.

### *Lacustrine Soils*

*Fine Sand and Sandy Loam.* The surface soil consists of yellowish-brown to black, fine sand and sandy loam, containing in places small amounts of gravel but usually free from stones or boulders. The subsoil consists of yellowish fine sand or sandy loam usually free from stones or boulders. The surface for the most part is nearly level or gently sloping. In places away from the streams the natural drainage is poor owing to the nearly level surface. The soil for the most part is well supplied with organic matter and, because of its nearly level surface and the nearness to the surface of the groundwater-level, is not easily affected by drought.

### *Glacial Till Soils*

*Clay Loam and Clay.* The surface soil consists of brown to black clay loam or clay containing in places stones and boulders. The subsoil consists of yellow clay with stones and boulders. The soils occupy over half the area. Their stony character is their chief objectionable feature. They are most stony along the tops of the low ridges and least stony along the sides of the ridges. In places the surface soil is nearly free from stones. The soil is well supplied with organic matter, the surface is gently sloping or has the form of low ridges and is usually naturally drained.

*Stony Loam.* The soil in the areas mapped as stony loam is somewhat similar to the clay loam and clay soils but is remarkably stony and, therefore, of little value for agriculture. It occurs chiefly in the morainic areas near the foot of Duck mountain. The surface is undulating or hilly and is partly timbered.

## BRICK-CLAYS

The lacustrine clays of glacial Lake Agassiz and alluvial brick-clays are not abundant. Silty clays in the valley of Mossy river are overlain by 6 to 10 feet of alluvial sand and silt and are exposed in the ravines made by small tributaries flowing into the river from the west. A section on the north bank of Duck river, 4 miles west of Cowan, shows about 20 feet of evenly bedded, silty clay overlain by 3 feet of sand and gravel. The clay contains a few scattered stones. Sections exposed along the north bank of Sclater river, $1\frac{1}{2}$ miles west of Sclater, show a few feet of stratified silty clay overlain by boulder clay. The stratified clays are similar to those of other parts of the Lake Agassiz basin. Their properties and brickmaking qualities at other localities in Manitoba have been described by J. Keele.[1]

## SAND AND GRAVEL

Sand and gravel for ballast, road metal, and structural purposes occur in the beach ridges and in the lacustrine sand areas. Practically the only gravel deposits are in the beach ridges. The largest ballast pit is worked by the Canadian National railway at Cowan. The principal gravel deposits

[1] Geol. Surv., Can., Mem. 24 and Mem. 65, pt. V.

occur in the two large beaches along the railway from Ethelbert to Cowan, but there are numerous smaller deposits in the beach ridges, chiefly in the west. The gravel and sand, owing to the limestone in the drift deposits, are markedly calcareous.

### WATER SUPPLY

Owing to the salt and mineral springs, it is difficult, in parts of the area, to obtain water for domestic purposes. The springs occur within a belt 1 to 6 miles wide along the south and west sides of lake Winnipegosis; and also in places on Red Deer peninsula and near Salt point. The saline waters come, probably, from the bedrock, for the surface waters are fresh. All but one spring—near the south end of Duck bay—issue from the boulder clay; this one apparently from the limestone. In the vicinity of the springs the groundwater, which is mostly fresh, becomes saline because of the slight surface slopes and deficient natural drainage. The salt water, being heavier, sinks beneath the fresh water in the depressions, and is not readily drained off. Well-water obtained by boring or digging to the groundwater-level in the vicinity of the springs is, therefore, likely to be salty. In places, however, for example at Winnipegosis, fresh water has been obtained by boring at places only a few yards from wells of saline water. Some of the wells are sunk partly in the bedrock, but most of the water supply comes probably from the drift deposits overlying the bedrock. It is stated that gypsum was encountered in one of the wells drilled into the bedrock at Winnipegosis. If so, it is probable that the water obtained from the bedrock is saline or mineralized like the springs, and fresh water is more likely to be obtained from the superficial deposits overlying the bedrock. It is possible that small freshwater streams flow along the joints and fissures in upper parts of the bedrock, but there is no way of locating these streams. Fresh water has been obtained in wells sunk on the low boulder clay ridges near saltwater marshes and below their level. The water occurs in gravel and sand beneath the nearly impervious boulder clay which apparently underlies the marshes and confines to the surface depressions the salt water derived from springs.

Probably, therefore, where saline springs occur, fresh water is more likely to be obtained in the drift deposits than in the bedrock. The wells should be located in the ridges rather than in the depressions, and the surface saline waters, if they are met, should be cased off. There is no way of definitely locating the freshwater wells, for, although the salt springs are scattered, they occur over a wide area and salt water may be struck in places where no springs issue at the surface.

The water supply in the west is abundant and good. It is readily obtained because of the nearness of the groundwater to the surface, usually only a few feet, except near the foot of Duck mountain where it is in places 50 to 100 feet from the surface. The numerous streams of pure fresh water flowing from Duck mountain also furnish an abundant supply. They are perennial streams and few of them go dry even in the driest seasons. Duck river is slightly saline for about 6 miles from its mouth, Pine river for about 2 miles, and Point creek for about 4 miles. The swamp waters where saline springs occur are unfit for domestic use, especially in dry seasons. The waters of the large lakes are fresh and potable. The waters of many of the small lakes are somewhat salty, and are unfit for domestic purposes.

# PART II

# UPPER WHITEMOUTH RIVER AREA, TOWNSHIPS 1 TO 10, RANGES 8 TO 18, EAST OF PRINCIPAL MERIDIAN, MANITOBA.

## INTRODUCTION

Owing to the growing scarcity of prairie land available for settlement in the western provinces, greater attention has been directed in recent years to the possibilities of the settlement of wooded and swampy areas near railways. One of the largest of these areas is in southeastern Manitoba, where nearly 3,500 square miles of wooded and swampy land in townships 1 to 10, ranges 8 to 18, is largely vacant. The greater part of this area is less than 100 miles from the city of Winnipeg and is well supplied with railways (very little of the area being over 20 miles from a line); but only a small part of the land is occupied by settlers, and the total population of the area in 1911, as shown by the census, was only 6,161, or 1·7 to the square mile. It was known that the area is almost entirely wooded and that a large part of it is swampy, but little information was available regarding the actual character and distribution of the soils and the possibilities of drainage of the swampy areas. The chief object of this report is to describe the character and mode of origin of the soils, the character and distribution of the sands, gravels, and clays of value for structural and other purposes, and the water supply.

### LOCATION AND AREA

The Upper Whitemouth River map-area includes townships 1 to 10, ranges 8 to 18, east of the principal meridian, in southeastern Manitoba, and embraces a land area of nearly 3,500 square miles. It is bounded on the south by the International Boundary and on the east by the boundary between Manitoba and Ontario. Of this area 2,650 square miles have been mapped. The remaining part is difficult of access in the summer because of extensive swamps.

Little was known of the region between lake of the Woods and Red River valley previous to the exploratory surveys of H. Y. Hind and S. J. Dawson in 1857-59.[1] The principal route from lake of the Woods to Red river was Winnipeg river, which, in spite of navigation difficulties, was generally used throughout the period of exploration and the fur trade. Two other routes were known; one, by way of Reed and Roseau rivers,[2] and another, a land route, from the northwest angle of lake of the Woods; but they were rarely used. During the winter of 1857-58 the area between lake of the Woods and Red river was examined by assistants of S. J. Dawson, and a survey line for a road was run from Red river to lac Plat (now Shoal lake) at the western extremity of lake of the Woods. In his report of 1859, Dawson described the district in a general way and recom-

[1] "Report on exploration of the country between lake Superior and the Red River settlement," Toronto, 1859. "Assiniboine and Saskatchewan exploring expedition," Toronto, 1859.
[2] "Journal de La Verendrye," Champlain Society, Toronto.

mended to the Canadian Government the construction of this road as part of the proposed highway and water route from lake Superior to Red river. It was not until the autumn of 1868 that construction was begun, and in the meantime, at the suggestion of Dawson,[1] the proposed route was changed and the northwest angle of lake of the Woods made the eastern terminus, instead of lac Plat. The road was completed in 1869-70 and for a time was known as Mr. Snow's road[2], but has since become generally known as the Dawson road after S. J. Dawson who, after his survey, was superintendent of the construction of the road.[3] The name was, however, more properly applied to the whole route from lake Superior to Red river. The road was traversed by a part of the military forces under Colonel Wolseley returning from Red river in 1870[4], and again by military forces the following year. It was used for a number of years by settlers and other travellers, and probably the first settlements in the district were made along this road. Old settlers say that some of the rails used in the construction of the Canadian Pacific railway in eastern Manitoba were brought over this road in Red River carts. After the construction of the railway in 1881 the road was practically abandoned and the eastern part beyond Birch river was impassable at the time the present examination was made.

The country along the road was described by G. M. Grant[5] who passed over it in 1872 and by G. M. Dawson[6] who traversed it in 1874.

An examination of the southern part of the region lying west of the lake was made by G. M. Dawson[6] who crossed it by Reed and Roseau rivers in 1873. H. Y. Hind and S. J. Dawson had intended passing by this route in connexion with the exploratory expeditions in 1857 but were turned back by a large force of Indians. The route was very seldom travelled and until the construction of the Canadian Northern railway in 1901 through the southwestern part of the area there were very few settlers in this part of the area. The construction of the railway was followed by a considerable influx of settlers along the line of railway. According to the census of 1901, there were, however, in the whole area only 837 inhabitants, exclusive of the Indians occupying a number of small reserves along the Interprovincial Boundary.

In 1914 the construction of the Greater Winnipeg Water District railway and aqueduct from Indian bay, Shoal lake, to the city of Winnipeg, a distance of 97 miles, was begun. The railway was built partly as an aid in constructing the aqueduct, which is intended to furnish a water supply for Winnipeg and partly as a colonization road. Eight townships in the area, along the line of the railway, were reserved for the Greater Winnipeg Water District settlement scheme and as a result of the construction of the railway and colonization efforts, this part of the area now has a number of settlers.

The construction of the Grand Trunk Pacific (National Transcontinental) railway in 1910, along the northern border of the area was accompanied and followed by an influx of settlers, and parts of the area, along Whitemouth and Brokenhead rivers, had been previously occupied,

[1]Russel, A. J., "The Red River country," Ottawa, 1869, page 179.
[2]Gunn, Donald, "History of Manitoba."
[3]Sessional papers, vol. III, No. 1, 1870, page 45.
[4]Hyshe, G. L., "The Red River expedition," 1871.
[5]"Ocean to ocean," Sanford Fleming's expedition, 1873.
[6]"Report on the geology and resources of the region in the vicinity of the Forty-ninth parallel," 1875.

owing to the good character of the land and proximity to the Canadian Pacific.

Townships 4 and 5, range 8, near Marchand, form parts of an area, originally largely wet and undrained, which was bought by a company a number of years ago, with the object of draining the land and offering it for sale. Much of the area has been drained and a number of roads have been built, but it is for the most part still unoccupied by settlers.

Small parts of the area are forest reserves, the most important being the Sprague limits in township 1, ranges 15 and 16, the reserves near Sandilands and Marchand, and that near Hazel in the northwestern part of the area.

## PREVIOUS WORK

Very little geological work had been done in the area. The geology of lake of the Woods was first discussed by Dr. J. J. Bigsby[1] in a paper published in 1852. He gives the results of an examination made in 1823 in connexion with the Boundary Commission Survey. H. Y. Hind, in his various reports of the "Assiniboine and Saskatchewan exploring expedition" organized by the Canadian Government in 1857-58, describes the surface geology of parts of southeastern Manitoba. S. J. Dawson in his "Report on exploration of the country between lake Superior and the Red River settlement, 1859," gives a general description of the area. The chief references to the surface geology of the region are found in the report by G. M. Dawson on the "Geology and resources of the region in the vicinity of the Forty-ninth parallel," Geological Survey, Canada, 1875. A. C. Lawson in his "Report on the geology of the Lake of the Woods region," Geological Survey, Canada, 1885, refers to the limestone drift of the southern part of the lake basin and discusses its origin. The area near the National Transcontinental railway, along the northern border of the district, was described by W. H. Collins, Geological Survey, Canada, in Guide Book No. 9, 1913, page 153.

The land has all been subdivided by Dominion Land Surveys and considerable information regarding the general character of the district is given on the township plans and in the reports of the surveyors, published by the Department of the Interior, Ottawa.

## CLIMATE

No meteorological records are available for the district itself, but records have been kept from 1885 to 1917 at Winnipeg, where the climate is very much the same as in the northern part of the area, and records from 1910 to 1917 at Warroad, Minnesota, show approximately the same conditions as in the southern part of the area.

The climate is continental in character, that is, it is characterized by greater temperature extremes and less humidity and rainfall than in regions near the coasts. The precipitation is less than that of the Great Lakes region, but greater than much of the Great Plains region to the west. The area is climatically well suited for the ordinary farm crops common to the temperate zone.

[1]Bigsby, J. J., Jour. Geol. Soc., London, 1852, vol. vii.

The mean annual temperature at Winnipeg is 36·2 degrees and is practically the same at Warroad. The mean temperature of the growing months, May to September, at Winnipeg is 60·0 degrees and at Warroad 59·3 degrees. January is the coldest month and July the warmest. February is, however, generally almost as cold as January and in some years colder. The mean temperature for June or August in some years also exceeds that of July. The average length of the crop season free from killing frosts at Winnipeg and at Warroad is about 100 days, but varies greatly from year to year. It is probably about the same throughout the greater part of the region here described. The average date of the last damaging frost in spring is about June 1 and the first in autumn about September 10. In the central parts of the area, which have a general altitude of 100 to 250 feet above lake of the Woods, and 400 to 500 feet above Red River valley, the crop season free from killing frosts is probably (because of the greater altitude) somewhat shorter than that of Winnipeg or Warroad.

The average annual precipitation at Winnipeg is nearly 21 inches and at Warroad nearly 22 inches. The precipitation throughout the greater part of the area is probably about the same as at Warroad. This is small compared with that of the Great Lakes region, but nearly 70 per cent is in the growing season, when it is most needed. The snowfall averages about 50 inches. Nearly all the precipitation in winter is in the form of snow, and winter thaws rarely occur.

## PHYSICAL FEATURES

The area may be divided into two parts, a "rocky, lake" area in the northeast, and a deeply drift-covered area in the southwest. The rocky, lake area is underlain by Precambrian crystalline rocks, partly concealed by drift deposits, and forms a comparatively small part of the whole area. It occupies the corner northeast of a line drawn approximately from the southwestern end of Shoal lake to Whitemouth river near the crossing of the National Transcontinental railway. The solid rocks outcrop over a considerable part of the area, but towards the southwest the outcrops become gradually smaller and fewer because of the thick deposits of drift. In the remaining part the drift, consisting of glacial till or boulder clay, glacial outwash, lake deposits of Pleistocene age, and Recent alluvial and swamp deposits, are in places, as shown by well borings, over 200 feet thick and probably average nearly 100 feet in thickness over the greater part of the area. The glacial till and outwash deposits form the great bulk of the drift. The glacial lake sediments and Recent deposits occupy a considerable part of the surface of the area, but rarely exceed 20 feet in thickness.

The rocky, lake portion of the area is a marginal part of the Laurentian plateau or Canadian shield and has a very marked local relief to the northeast, but becomes gradually of less relief towards the southwest. The remaining and greater part of the area is a drift plain or plateau of varying but mostly very low relief.

The region is, in great part, wooded in contrast with the treeless plain or prairie, which begins a few miles from its western edge and borders Red River valley. Although it has very little more precipitation than the

treeless area to the west, it is wooded because of the nearness to the surface of the groundwater-level—owing to the flat and undrained character of much of the surface and the clayey character of the sediments—and because of the protection from forest fires afforded by numerous and extensive swamps.

## RELIEF

The rocky, lake part has a local relief of 100 to 200 feet and a general elevation of 1,100 to 1,200 feet above the sea. West of this along the route followed by the National Transcontinental railway the surface is nearly level and descends from 1,100 feet east of Whitemouth river to 900 feet at the northwestern corner of the map-area. Along the line of the Greater Winnipeg Water District railway, which is paralleled by the pipe-line bringing from Shoal lake the water supply of Winnipeg, the surface is for the most part very even. Shoal lake has practically the same elevation as lake of the Woods, 1,060 feet, and the fall in the pipeline from the lake to Winnipeg, a distance of 97 miles, is 300 feet. The summit or divide along the line is 6 miles west of, and only 15 feet above, the lake. The summit is a broad, swampy plain interrupted here and there by low, rocky islands or drift ridges, and extends south to the southern border of the area, a few miles west of Buffalo bay on lake of the Woods. The surface along the railway westward from the summit has a fairly even slope of a few feet to the mile and practically no cuts or fills of importance were necessary in the construction of the railway.

The highest part of the area is in the southwest and is an irregularly-shaped upland tract or drift plateau occupying about 200 square miles. The plateau has a general altitude of 1,150 to 1,250 feet, but rises in places to 1,300 feet. It has a maximum altitude of 500 feet above Red River valley on the west and 250 above lake of the Woods on the east. It is crossed by the Canadian National railways and extends along the railway from Bedford to South Junction. It extends for 15 miles northeast from Bedford and for the greater part of the distance has a steep front 50 to 100 feet high, overlooking a nearly level plain towards the northwest. This sharp rise in a region of low general relief is a striking feature, when viewed from the west. The upland is known locally as Cypress mountain. The greater part lies northeast of the railway, but spur-like ridges extend south from Bedford into the southern part of the area. The surface is largely undulating and in places is characterized by numerous irregularly-shaped hills with intervening, undrained hollows. The highest point on the railway is about one-half mile northwest of Badger station, where the ground has an altitude of 1,260 feet.

Along the International Boundary, in a distance of 56 miles from the western edge of the area to lake of the Woods, the maximum relief is only about 100 feet. The highest point, as shown by the levels taken by the Boundary Commission, is about 12 miles west of the lake and has an altitude of 1,097 feet, or 37 feet above lake of the Woods. The lowest point is in the valley of Roseau river and has an altitude of 1,000 feet. The swamp forming the divide between the headwaters of Reed and Roseau rivers is only about 30 feet above lake of the Woods.

The lowest part of the whole area is in the valley of Brokenhead river in the northwest corner of the area, where the river at the Trans-

continental Railway bridge has an altitude of 870 feet. The maximum relief of the whole area is, therefore, about 430 feet.

## DRAINAGE

Throughout the greater part of the area the surface drainage is poorly developed and large swampy tracts, practically untouched by stream erosion, are prevalent. These tracts are due to the low surface gradients, the impervious character of part of the drift deposits, and to the growth of a dense mat of vegetation which holds water like a sponge, so that the run-off is mainly by ground water and exceedingly slow. Also, the area is geologically very youthful and sufficient time has not elapsed since the deposition of the drift deposits for the development of stream valleys except to a very small extent. In many places, too, low ridges of sand and gravel, marking shore-lines of an ancient lake, act as dams and prevent natural drainage.

The streams which head in the upland area of the southwestern part of the region have well-defined valleys, in places 30 to 40 feet deep throughout their course in the upland tract, but in the lowland area the valleys are poorly defined and the streams have no definite channels through the swampy areas. The main branch of Whitemouth river has no well-defined channel from Whitemouth lake to a point about 6 miles south of the crossing of the Dawson trail, and in times of flood overflows its banks in this part of its course. The lake has an altitude of about 1,125 feet above the sea and the fall of the river in this poorly-defined part of its course is about 50 feet or 2 feet to the mile. From the trail north to the crossing of the Greater Winnipeg Water District railway the river flows in a well-defined valley with banks 10 to 40 feet high. Rapids caused by accumulations of boulders occur at a number of places, both above and below the Dawson trail. In the lower part of its course the river has a fairly well-defined valley averaging about 10 feet in depth. The total fall in the river from Whitemouth lake north to the crossing of the National Transcontinental railway is about 200 feet. The other streams of the area have for the most part poorly-defined valleys and their banks are in places subject to overflow.

Lakes are not numerous in the deeply drift-covered part of the area. Whitemouth lake, the largest, is a remnant of the great glacial lake known as Lake Agassiz which covered the greater part of the region; for it is held in on the north side by beach deposits of the glacial lake, through which the outlet stream of the present lake has cut a narrow channel. The lake has a maximum depth of only about 20 feet and is for the most part less than 10 feet deep. Small lakes are numerous in the northeastern part of the area owing to the uneven, bedrock topography and irregular and scanty deposition of drift deposits, which is in contrast with the evenly aggraded surface of the deeply drift-covered part of the region.

## VEGETATION

The greater part of the area is forest covered as an abundant growth of trees is favoured, in spite of the comparatively small amount of rainfall and occasional, dry seasons, by the nearness to the surface of the ground-water-level.

The flora of the northeastern rocky, lake region is like that of the southern part of the great Laurentian Plateau region of Canada. Most of the forest trees are coniferous, the banksian or jackpine predominating. Red and white pine formerly were widely distributed over the rocky areas and to a less extent in the highland drift area, but have been largely cut for lumber or destroyed by forest fires.

In the southeastern, deeply drift-covered part of the area deciduous trees are more common; the aspen and balsam poplar are the most abundant and occupy the nearly level or gently sloping areas. The highland drift areas are clothed chiefly with jackpine, the sandy and gravelly ridges with groves of jackpine and white birch; the poorly-drained areas, which form a large part of the map-area, with white cedar, tamarack, and spruces. The cedar and white spruce most frequently occur where the surface drainage is poorly developed and where there is only a small thickness of peat. The peat bogs are clothed mainly with tamarack and black spruce, except in their central parts which are frequently treeless, and are in places floating bogs. White elm, green ash, and Manitoba maple occur sparingly in the better-drained areas and most commonly along the banks of the streams; and alder and willow occur abundantly throughout. Marshes supporting a growth of wild grasses and forming in places natural hay meadows occur chiefly in the western and southwestern parts of the area. They differ from the bogs in that the peaty material in them is usually shallow and is composed of partly decayed grasses rather than peat moss. The marshes are covered chiefly with wire grass, but in places Blue-joint and Red-top hay occurs, particularly along streams, as for example along Rat river where small amounts of mineral matter mixed with the peat are deposited when the stream overflows. Wire grass is gathered from the large marsh near Caliento and utilized in the manufacture of mattresses.

## GEOLOGY

The solid rocks are Precambrian. They underlie the northeastern part of the area east of Whitemouth river and may extend farther west beneath the drift. The most westerly outcrop of Precambrian rock along the National Transcontinental railway is at Elma at the crossing of Whitemouth river. Along the Greater Winnipeg Water District railway outcrops occur in the area between the crossings of Whitemouth and Birch rivers. Outcrops occur also along the Interprovincial Boundary between Harrison creek and Stony point on lake of the Woods, but no outcrops are known farther west. At La Broquerie, limestone is reported to have been struck at a depth of about 100 feet in drilling for water. It is probable that the western and southwestern parts of the area are underlain by Palæozoic limestone, but the line of contact between the Precambrian and the Palæozoic is everywhere concealed by drift and cannot be demarcated by the well borings which reach bedrock.

The solid rocks are overlain by unconsolidated deposits of Pleistocene and Recent ages. The Pleistocene deposits consist of glacial till or boulder clay, glacial outwash deposits of stratified sand and gravel, and deposits formed in glacial lakes. During Pleistocene time great ice-sheets or continental glaciers advanced from the north across the

region and transported large quantities of boulders, sand, and silt. When the ice melted it left the surface covered with accumulations of this transported material, the glacial drift. Near the close of Pleistocene time, when the ice-sheets began to melt oack towards the north, the northward drainage of the Red River Valley region was ponded between the retreating ice-front and the high land to the south, and a great lake—known as glacial Lake Agassiz—came into existence. This lake, named by Warren Upham[1] was, at the time of his work, supposed to have covered all the area. Upham showed that, for a time the lake drained south by way of the Mississippi and that, at a later time, successively lower outlets were opened towards the northeast; that during the period of southward outflow a series of beaches were formed because of uplift of the land and cutting down of the outlet; and that during the period of northward or northeastward outflow other and lower beaches were formed as the land was uplifted and as successively lower outlets of the lake were uncovered by the retreat of the ice-sheet. He showed that a considerable part of the uplift was accomplished during the existence of the lake and that a series of moraines marking the stages of halt of the ice-sheet during its retreat occur at different places in the lake basin. The present work has shown that all the Upper Whitemouth River area, except the higher parts of the drift plateau, was covered by the lake during its early stages, but that the highest beaches of the lake are not represented in it. The plateau is surrounded by a well-developed beach which is probably the Upper Campbell beach as named by Upham, and described as one of the lowest beaches formed during the period of southern outflow of the lake. A few beaches occur above this one, but the absence of the highest beaches of the lake and the presence of numerous undrained basins, free from lake deposits, in the morainic areas, that form part of the drift plateau, show that the moraines mark the position of the ice-border during an early stage of the lake. The great strength and continuity of the Upper Campbell beach show that the lake must have persisted at the level of the beach for a considerable length of time. The fact that the stratified Lake Agassiz clays below the level of the Campbell beach rest in places on the eroded surface of stratified clays of an early stage of the lake (as was noted[2] in the southern part of lake of the Woods and also in a section exposed in the construction of the Greater Winnipeg Water District aqueduct at the summit level 6 miles west of Shoal lake) shows that the lake was partly drained and was again raised at least as high as the Upper Campbell beach. The great strength of this beach and the cutting down of the southern outlet of the lake to the level of the beach—which probably took place during the early stage of the lake—appear to show that it marks the upper limit of the second stage of the lake.

The Recent deposits consist of alluvial flood-plain deposits of the present streams, wind-blown sand, and swamp and pond deposits of muck and peat.

[1]Upham, Warren, Geol. Surv., Can., 1890; U.S. Geol. Surv., 1890.
[2]Geol. Surv., Can., Mem. 82, 1915, p. 66.

# PLEISTOCENE DEPOSITS

## TILL SHEETS AND GLACIAL OUTWASH

Glacial till, the unstratified deposit of the ice-sheet, occupies the surface or is only very thinly covered by stratified deposits, over the greater part of the area, and forms a considerable part of the superficial deposits.

There are probably two distinct till sheets. No sections showing the two tills are known, but the presence of two sets of glacial striæ trending in quite different directions and the evidence furnished by well borings show that the lower part of the drift is quite different in character and origin from the upper part. One set of striæ, probably the older, trends southwest, and the other southeast. The lower part of the drift was derived from the northeast and contains little or no limestone. The upper till sheet was derived from the north and northwest and contains an abundance of limestone boulders. In the western and southwestern parts of the area numerous flowing wells have been obtained by boring. The borings show that an extensive sheet of sand and gravel occurs beneath the upper till; and the water from these gravels is soft, showing the absence of limestone. The deepest well, so far as known, in the district, was bored at Vassar station to a depth of 285 feet without reaching bedrock. A considerable thickness of sand and gravel overlain and underlain by "hardpan" was stated to have been passed through in this boring. In some of the borings vegetal matter was said to have been brought up from considerable depths. At Buffalo point on lake of the Woods, thin beds of lignite and stratified clay are exposed at extreme low water. They are overlain by stratified Lake Agassiz deposits and are apparently of Pleistocene age, but their relation to the underlying beds is not shown.

It is probable, therefore, that two tills of different ages occur in the region and are in places separated by thick deposits of sand and gravel, probably glacial outwash associated with the earlier advance of the ice from the northeast. A remarkable feature is the apparent absence of lake clays associated with the earlier advance of the ice, the sands and gravels indicating comparatively free drainage from the ice-sheet. Peat and lignite beds in the drift deposits may possibly indicate a lengthy period of retreat of the ice previous to the last advance, but the evidence is too scanty to be of much value in this connexion.

The upper till sheet is markedly calcareous owing to the fact that the ice advancing from the direction of the basin of lake Winnipeg passed over areas underlain by limestone. It is possible also that limestone forms the bedrock in part of the area itself. Limestone is abundant in the drift southwest of a line drawn from the northwest angle, near the mouth of Harrison creek to the crossing of the National Transcontinental railway over Whitemouth river. The till forms the surface in parts of the area and in places has a remarkably even surface which is nearly as smooth as the surface of the lake deposits but has a greater slope. The even surface is due partly to erosion by wave-action during the existence of Lake Agassiz and partly to deposition as ground moraine formed beneath the ice-sheet or from the material enclosed in the ice and deposited after its melting. In places the surface is very stony because of erosion

of the till by wave-action and concentration of the boulders at the surface, the fine material being washed away. In the northeastern part of the area, where the till is largely derived from the Precambrian rocks, it is for the most part sandy and very stony; the limestone till is clayey in character and in places contains comparatively few stones.

Glacial outwash deposits in the forms of kames, eskers, or outwash fans are rarely exposed at the surface. The material carried by streams from the ice-sheet during the period of final retreat was deposited in the lake which bordered its front and formed lacustrine deposits. Sand and gravel deposits which appear to be outwash from the ice-sheet occur in the highland area north of Woodridge and near Sandilands. They were formed, probably, in the waters of Lake Agassiz during its early stage, and are not subaerial deposits. A gravel deposit, in which a gravel pit has been opened by the government, occurs northeast of Birch river. It was probably formed before the last advance of the ice from the northwest and is associated with the great sheet of outwash sands and gravels which, as shown by borings, underlies the upper till sheet and extends throughout the southwestern part of the area.

## TERMINAL MORAINES

A series of terminal moraines, marking positions of the ice-front during the period of final retreat, occur in the southwestern part and form a considerable part of the highland drift area. They form a confused series of ridges, showing in places typical morainic topography consisting of numerous irregularly-shaped hills and intervening, undrained basins. They trend in various directions and no definite system of arrangement or order of deposition is apparent. The general direction of ice movement, during the latest stage of glaciation, as shown by the glacial striæ and by the calcareous character of the upper till sheet, was towards the southeast. The direction of retreat of the ice-sheet, however, during the early stage of Lake Agassiz, was towards the north and northeast; for the whole northern part of the lake basin extending from the highland area northeast of the Upper Whitemouth area to the highlands in northwestern Manitoba must have been occupied by the ice-sheet which acted as a dam and held up the lake waters. The steep front of the morainic area, facing northwest from Bedford, indicates that the ice which deposited the moraine lay to the northeast and was bordered on the northwest by Lake Agassiz. The lake extended for a considerable distance north in the Red River valley, and occupied a large re-entrant angle in the ice-front. The presence of outwash sands near Sandilands and Woodridge, on the southwest side of the moraine, also shows that the ice lay towards the northeast. It is possible that the moraines were formed in part by ice advancing from the northwest and in part by ice advancing from the northeast, and that this accounts for their irregular mode of deposition and apparent lack of systematic arrangement. The movement of the ice towards the southeast took place late in Pleistocene time and was probably due to deflexion of the ice by the Manitoba escarpment in western Manitoba.

## GLACIAL LAKE AGASSIZ DEPOSITS

### *Raised Beaches*

Beach deposits of sand and gravel, marking shore lines of Lake Agassiz at different stages of its existence, occur at numerous places and at various altitudes throughout the district. They are, for the most part, relatively long, narrow ridges 6 to 10 feet high and 100 to 500 feet wide and are wave-built barrier beaches or bars, such as are characteristically formed on a low, shelving shore. Wave-cut terraces occur in places in the highland drift area where the original slopes were somewhat abrupt. The steep front of the highland drift area extending northeast from Bedford is in part due to wave-cutting; and other wave-cut cliffs occur at higher levels but only in the highland area; the wave-built bar is the dominant feature marking the ancient shore-lines throughout the area. Many of the roads of the district are located on beach ridges which, because of their natural drainage and gravelly character, are well adapted for the purpose and form a means of travel through parts of the district that would otherwise be difficult of access. The beaches, however, in many places act as dams and prevent natural drainage, and are thus in part the cause of swampy conditions in large parts of the area.

Only a few of the beaches can be definitely traced for great distances because they are mostly discontinuous and poorly developed. The best-developed beach is nearly continuous around the highland area to the southwest and because of its strength can usually be identified at different places. It is probably the Upper Campbell beach, as named by Upham; for, as shown by a determination of the number and altitudes of the beaches below this beach and westward to Red river, the same number of beaches occur as in the western part of the lake basin where they were mapped and described by Upham. This beach is separated by a vertical interval of 25 to 30 feet from the next lower beach, which is followed downward by several others at different elevations. Several beaches occur above the Upper Campbell beach, but the highest beaches in the southern and southwestern parts of the lake basin do not occur in this area. The beaches occur at various elevations from 915 to 1,250 feet above the sea. They were originally horizontal but now rise progressively towards the northeast, because of differential uplift, which has taken place since the formation of the beaches.

### *Late Glacial and Post-glacial Changes of Level*

The character and extent of the late glacial and post-glacial uplift in the Upper Whitemouth area may be determined approximately from a comparison of the altitudes of the beaches at different places in the district and by comparing their altitudes in the area with their altitudes at the southern outlet of the lake. The direction of maximum uplift is shown by lines drawn at right angles to the isobases (lines drawn through points of equal elevation of a beach). The general direction of maximum uplift is about north 35 degrees east, but it probably varies in different parts of the area. The beach at Caliento in the southwest is probably

the same beach as that near Sirko at the International Boundary, and has the same elevation. An isobase may, therefore, be drawn through these two points. The Upper Campbell beach at Bedford has an elevation of 1,125 feet and has nearly the same elevation between South Junction and Sprague in the southeast. This beach has an elevation of 1,117 feet near Menisino on the southwestern side of the highland area. The rate of uplift, as shown by a comparison of the altitude of the Upper Campbell beach at Menisino and its altitude on the northeast side of the highland area near Whitemouth lake, is about 2 feet to the mile. It is probable, therefore, that the isobases of uplift curve slightly around the southwest side of the highland area, for the altitude of the beach at Menisino is too great to permit of an isobase being drawn directly from Bedford to near Sprague. The beach at Gravel Pit Spur in the southeast is the first well-developed beach above lake of the Woods and has an altitude of 1,102 feet. A beach on the Interprovincial Boundary, about half-way between Harrison creek and Buffalo bay on lake of the Woods, is also the first beach above the lake and is, therefore, probably the same beach as the one at Gravel Pit Spur. It has an altitude of 1,137 feet. The two localities are 18 miles apart and the direction is approximately that of maximum uplift. The rate of maximum deformation of this beach is, therefore, about 2 feet to the mile. The lowest beach in the district occurs at Vivian, in the northwest, where it has an elevation of 915 feet and near Siding No. 3 on the Greater Winnipeg Water District railway, where it has an elevation of 912 feet. It is the first well-developed beach east of Red river, and is one of the lowest beaches of the lake. The same beach crosses the Canadian National railway 2½ miles southeast of St. Anne on the Dawson trail, a few miles west of the western border of the area, where it has an elevation of about 870 feet. It extends southwest along the eastern border of the Red River prairie as far as Ridgeville near the International Boundary and was formerly known as "The Big Ridge." It has an elevation, at a point 1½ miles east of Ridgeville, of 850 feet. The rate of maximum deformation of this beach, from Ridgeville to St. Anne, is about 1 foot a mile; and from St. Anne to Vivian about 2 feet a mile. The rate of uplift, therefore, increases rapidly towards the northeast. In the southeast, where the rate of deformation of the Upper Campbell beach is about 2 feet a mile, the rate of deformation of the lowest beach is probably about 1¾ feet a mile. The fact that the rate of deformation of one of the lowest beaches of the lake is nearly as great as that of the Upper Campbell beach shows that a considerable part of the uplift following the second stage of the lake in this area took place after the disappearance of the lake. Uplift took place, however, during the early stage of the lake, for the beaches above the Upper Campbell beach diverge towards the northeast, that is, they are separated by marked vertical intervals, whereas, as shown by Upham, they converge at the southern outlet of the lake and are there separated by very small vertical intervals, the result of cutting down of the outlet. The beaches below the Upper Campbell beaches in this area do not appear to diverge to any marked extent, for they have nearly the same rate of tilt. It is, therefore, probable that there were two periods of uplift: an early period, during the early stage of the lake and during its partial disappearance; and a later period during the latter part of the second stage of the lake and following its final disappearance. The total amount of uplift in the area

cannot be determined, because the highest beaches of the lake are not represented. The amount of uplift of the second period, at Bedford, is shown approximately by a comparison of the altitude of the Upper Campbell beach at this locality and its altitude at the southern outlet of the lake. It has an altitude at Bedford of 1,125 feet, and at the southern outlet of the lake is 990 feet.[1] The minimum amount of uplift at Bedford is, therefore, 135 feet and is probably greater in the northeast. The total uplift is much greater, for the highest beach near Woodridge has an altitude of about 1,250 feet.

*Lacustrine Deposits*

Lacustrine deposits of Lake Agassiz are widespread, but in most places are thin, and rarely exceed 20 feet in thickness. They are thickest along Whitemouth river. They consist of stratified sand, silt, and clay, the sand being the shallow-water near-shore deposit and the silt and clay, deposits formed in deeper water. The sand is widespread in the southeastern, higher parts and the clay is nearly absent. The clay occurs most abundantly in the northern and lower parts. The silt and clay have no great thickness, partly because the lake fell gradually and the deposits were, therefore, washed down to the lowest parts of the lake basin, and partly because the material was not abundant. Two series of lake clays of somewhat different character occur, one belonging to the early and the other to the later stage of the lake. The series are separated by an erosion surface exposed at several places along the south side of lake of the Woods and at the summit-level of the aqueduct, 6 miles west of Shoal lake. The erosion surface was not found, however, in sections exposed at lower altitude along the line of the aqueduct towards Winnipeg. Sections exposed along Red river at Winnipeg show in places 10 feet of stratified silts unconformably overlying 10 to 20 feet of thinly laminated clays, but the upper silts may be alluvial in origin and not the deposits of the second stage of the lake. The erosion surface shows that the lake was partly drained and was again raised to a higher level. It occurs 50 feet or more below the level of the Campbell beach, which is nearly the lowest beach connected with the southern outlet of the lake. It is probable, therefore, that a lower outlet of the lake was opened, by a retreat of the ice towards the northeast, and that this outlet was again closed by a re-advance of the ice.

The lacustrine clays of the second stage of the lake are in general highly calcareous and yellow and were derived largely by wave-erosion of the calcareous till, and only to a small extent by stream erosion; for no large land areas existed in the district at the time of deposition of the clays. They were not formed by outwash from the ice-sheet (for they are well oxidized) and contain, in places, numerous fossil freshwater shells which could scarcely have lived in the waters of the lake, had the ice-sheet been close at hand. Shells were found scattered through the 16 to 20 feet of clay which is exposed in the aqueduct cutting on the summit-level, 4 miles west of Shoal lake. The clays are clearly not stream

[1]U.S. Geol. Surv., Mon. XXV, p. 476.

deposits, for they occur on a broad summit plain where their only possible source was by wave-erosion of the isolated drift hills. The fossil shells as determined by E. J. Whittaker are of the following species:

*Lampsilis luteola* Lamarck.
*Strophitus edentulus* Say.
*Sphærium rhomboideum* Say.
*Sphærium stamineum* Conrad.

Regarding the fossils Mr. Whittaker states:

"*Lampsilis luteola* is a widely distributed form at the present time. It occurs throughout Canada except on the Pacific slope, and throughout the Mississippi drainage. *Strophitus edentulus* has a similar distribution except that it is not found north of lake Winnipeg. *Sphærium rhomboideum* is found from Michigan northwestward to Alaska, while *S. stamineum* does not occur north of the Saskatchewan drainage basin."

Fossil shells were also found in the Lake Agassiz deposits at two localities, by Upham[1] and by the present writer, in the Rainy River district. They occur in the clays of the later stage of the lake but not in those of the early stage.

The lacustrine clays of the early stage of the lake are well-laminated silty clays, and were formed probably from material discharged by the retreating ice-sheet. These clays are not silty in character, although they are in part glacial silt. Their clayey character, or the extremely fine size of the particles composing the clay, is probably due to erosion of the fine-grained shales which underlie parts of Manitoba over which the ice-sheet passed.

## RECENT DEPOSITS

The alluvium consists of flood-plain deposits of sand, silt, and clay which border parts of the streams. Except in the highland area and in part of the lower course of Whitemouth river, where the streams have well-defined valleys and banks high enough to contain the flood waters, the streams, in times of flood, deposit silt and clay on their flood-plain. The alluvium is usually only a few feet thick and extends in a narrow border, rarely a quarter of a mile wide, along the streams. In places natural levees are built up and the banks are slightly higher near the stream than farther away. They, therefore, help to produce swampy conditions by preventing free drainage. Because of the growth of vegetation during the times when the streams are not in flood, the alluvial deposits contain large amounts of organic matter.

Deposits of wind-blown sand occur chiefly in the highland area near Sandilands, and are not extensive. They consist in part of ancient dunes which are partly timbered, chiefly with jackpine, and are not at present live dunes. In places, however, where the trees have been destroyed by fires the sand is drifting. The sand was originally deposited in the shallow waters of Lake Agassiz and along its shores, and is easily blown because of the absence in it of silt and clay that would act as a binder, and favour the growth of vegetation.

Large areas of peat occur along Whitemouth and Birch rivers, but are only 1 to 3 feet thick. The peat consists almost entirely of organic matter in a partly altered condition, the fibrous nature and vegetable origin of the material being usually quite apparent. Only in its lower

[1] Ibid, p. 237.

part is the material true peat, the upper part being compacted moss and other vegetable matter only slightly altered. Part of the peaty material formed on the flood-plains of the streams contains small amounts of mineral matter deposited in times of flood. It is more altered than the swamp deposits away from the streams and is more like muck than peat. The organic material forming the bogs is only slightly altered, because the groundwater-level is near the surface and oscillates in level only slightly, so that there is little opportunity for oxidation, and because ground-ice persists in the bogs until late spring or early summer and the groundwater is always cold.

# ECONOMIC GEOLOGY

## SOILS

### GENERAL CHARACTER AND DISTRIBUTION OF SOILS

The soils of the area are practically all drift soils, that is, they are derived from superficial deposits of Pleistocene and Recent ages. The soil differs from the deposits upon which it is developed in that it has been affected by the processes of weathering, by the gradual incorporation of animal and vegetable matter, and has been acted upon by life in some form, so that it is productive.

On the accompanying map (No. 1802) the various soils are shown by different colours. The colours also represent the surface deposits upon which the soils are developed. The descriptive names of the soils, *e.g.*, sandy loam, refer to the surface soil to a depth of about 6 inches and are based on the texture of the soils as shown by mechanical analyses made by C. J. Lynde, Professor of Physics, Macdonald College, Que.

The soils have been derived chiefly from glacial and glacial lake deposits, which are highly calcareous; hence, as a whole, they are calcareous especially in the subsoil portion; but in the northeast, overlying Pre-cambrian rocks, the soils are only slightly calcareous. The surface soil is usually sufficiently leached to eliminate a part of the lime, but the subsoil retains large amounts.

The soils have the light to medium dark colours usual in timbered regions, and lack the deep black of the prairie soils. There is a marked difference in the colour of the soils of this area and those of the Red River valley on the west. This difference is due mainly to vegetation. The dense mass of roots of the prairie grasses furnishes a large supply of organic matter which is readily altered to the humus that gives the prairie soils their deep black; whereas, in the timbered soils the roots of trees and shrubs are less abundant and do not readily form humus. Forest fires, also, more thoroughly destroy organic matter than do prairie fires. The light colour and small amounts of humus in the soils of the timbered areas are most pronounced in the sandy upland areas clothed with jackpine, for little grass grows on these areas and the pine-needles and rootlets, because of their resinous character, are remarkably resistant to decay, and form very little humus. The muck and peat soils are brown to black, the dark shade being more pronounced in the muck soils in which the organic matter is more decomposed. The alluvial soils are dark owing to the abundant organic matter. The æolian and beach soils are light in colour,

indicating a low organic matter content. The till and outwash sand soils of the upland areas clothed with jackpine are also light. The lacustrine clay loam and clay are dark—in places nearly as dark as the prairie soils of the Red River valley.

The lightest soils are the æolian and beach soils, and the fine sand and sandy loam of the till and glacial outwash. They occupy a considerable part of the highland drift area and numerous small areas throughout the district; and, on account of the relief of the surface and porous character of the material, are easily drained and are, therefore, easily affected by drought. The lacustrine fine sand and sandy loam soils are also light, but because of their nearly level or gently sloping surface and the nearness to the surface of the groundwater are not so easily affected by drought. The heaviest soils are the lacustrine clay loam and clay and the fine sandy loam of the glacial till.

The peat and muck soils consist of organic matter, with only a small amount of mineral matter. The alluvial soils contain much organic matter and occupy the flood-plains of the present streams.

*Areal Distribution of Soils*

| | Square miles |
|---|---|
| Swamp: muck and peat | 1,447 |
| Æolian: dune sand | 10 |
| Alluvial: fine sand and sandy loam | 12 |
| Beach: gravelly sand and coarse sand | 49 |
| Lacustrine: fine sand | 343 |
| Sandy loam | 88 |
| Clay loam and clay | 18 |
| Glacial till: fine sandy loam | 263 |
| Stony loam | 96 |
| Fine sand and sandy loam | 184 |
| Total area | 2,510 |

The total land area mapped is 2,650 square miles, of which 140 square miles have been mapped as bedrock outcrop. These outcrops occur in the northeast and include small areas of soil, in most places forming a thin cover to the rock. Much of the area is timbered and as a whole the region is better adapted for forest growth than for agriculture.

*Swamp Soils*

*Muck and Peat.* The muck and peat soils consist largely of organic matter in various stages of decomposition and vary in depth from 1 to 25 feet or more. The muck contains the greater amount of mineral soil and the organic matter is more decomposed. The formation and preservation of the peat are due to the groundwater near the surface. Drainage, by lowering the water-level, brings about atmospheric oxidation and decomposition of the peat and produces a mucky soil. In areas covered by 1 to 3 feet of peat, the peat largely disappears after drainage and cultivation, for it is greatly reduced by oxidation and when mixed with the undersoil forms a rich, mucky soil. The muck areas are small and occur—notably along Rat river—where small amounts of mineral matter, deposited in times of flood, are mixed with the peat. They are as a rule marked by a luxuriant growth of wild grasses and form natural hay meadows.

The peat bogs are widely distributed and are most extensive in the central part. The surface of the bogs is for the most part nearly level, but in places has a slope of 10 feet, or even more, a mile. Some of the small areas occupy natural depressions which have no visible outlet, but for the most part the bogs occupy areas which are so nearly level that the natural drainage is deficient and swampy conditions prevail. In many places beach ridges act as dams through which the water seeps slowly and prevents free drainage. In nearly all cases the bogs have at least a slight slope, so that artificial drainage is possible. The large bog south of the Dawson trail and partly drained by Whitemouth river would be very difficult to drain because of its extent, low gradient, and the few streams which traverse it. Large areas, however, along the lower parts of Whitemouth river and along Birch river are more favourably situated for artificial drainage, for the present streams have fairly well-defined valleys into which ditches might be led.

The peat of the greater part of the area is not markedly acid because of the presence of an abundance of lime in the under soil. In the northeast where the limestone drift is absent, the peat is acid, as is shown by the coffee colour of the water. In other parts the swamp waters are usually clear. The bogs of the west and southwest are underlain chiefly by sand. In the north, along the valleys of Whitemouth and Birch rivers, they are underlain chiefly by stratified silts and clays.

The peat has been largely formed by the gradual accumulation of vegetable matter in swamps and shallow ponds and, therefore, contains only a small amount of mineral soil, and is deficient in some of the mineral elements, especially potassium, necessary for the growth of plant life. The peat contains a large amount of nitrogen, one of the essentials for the growth of plants, but the nitrogen in peat is largely in a form not available for plants. In order to render the nitrogen available, it is necessary to convert the peat, at least in part, into humus. This is accomplished partly by drainage, cultivation, and aeration of the soil. The process is greatly aided by liming, to correct the acid character of the peat, and by applications of manure. Where the peat is thin, and has been mixed to some extent by cultivation with the underlying sand or clay, or where the peaty material contains sufficient mineral matter, a mucky soil is produced, which is usually highly productive. Where the peat is thick it is of low agricultural value and requires fertilizers.

### *Æolian Soils*

*Dune Sand.* The areas occupied by dune sand are small and occur chiefly in the highland area near Sandilands. The soil is of little agricultural value, chiefly because if cultivation is attempted the sand is likely to drift. The areas are mostly forested with a sparse growth of jackpine and only in places is the sand drifting. If the forest growth were removed, "blow outs" would undoubtedly occur.

### *Alluvial Soils*

*Fine Sand and Sandy Loam.* The alluvial fine sand and sandy loam soils occur in narrow bands where the streams overflow or have in the past overflowed. They occur chiefly along Whitemouth and Birch rivers. These streams in their lower parts only rarely overflow, but in the upper parts are subject to annual floods. Rat river overflows its banks in most years.

The alluvial soils are characterized by their high content of organic matter, so that they are in places mucky in character and are highly productive.

### *Beach Soils*

*Gravelly Sand and Coarse Sand.* The surface soil of the beach soils consists for the most part of white or yellow-to-brown sand containing a greater or less proportion of gravel. The subsoil consists of light-coloured sand with gravel and stones. The soil in most places contains a low percentage of organic material.

The beach soils occupy small scattered areas. The surface is in the form of low and relatively long, narrow ridges. Because of the ridged surface and loose, porous character of the soil, the natural drainage is usually excessive and the soil is easily affected by drought.

### *Lacustrine Soils*

*Fine Sand.* The surface soil of the lacustrine fine sand consists for the most part of brown, fine sand containing in places a small amount of gravel but generally free from stones or boulders. It is rarely black and contains only moderate amounts of organic matter. The subsoil consists of yellowish, fine sand or sandy loam generally free from stones or boulders. In places the surface soil and subsoil are sandy loam. The surface soil is only partly leached. One sample was found to contain 1·37 per cent of lime and the subsoil 4·14 per cent.

The fine-sand areas occur throughout the district and except the swamp areas are the most extensive.

The surface is nearly level or gently sloping. In places the natural drainage is poor, owing to the nearly level surface, but for this reason and the shallow groundwater-level, except in the highland areas, the soil is not so readily affected by drought.

*Mechanical Analyses of Lacustrine Fine Sand*

| Soil | Fine gravel 2 to 1 mm. | Coarse sand 1 to 0·5 mm. | Medium sand 0·5 to 0·25 mm. | Fine sand 0·25 to 0·1 mm. | Very fine sand 0·1 to 0·05 mm. | Silt 0·05–0·005 mm. | Clay 0·005– mm. |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % |
| Surface soil....... | 1·0 | 5·0 | 4·0 | 24·3 | 52·3 | 9·8 | 3·6 |
| Subsoil.............. | 0·0 | 0·0 | 0·0 | 9·0 | 83·5 | 5·0 | 2·5 |

*Sandy Loam.* The surface soil of the lacustrine sandy loam consists of brown to black, sandy loam or fine, sandy loam generally free from stones or boulders. The subsoil consists of yellowish or grey clay loam or clay. The depth of the surface sandy material varies from a few inches to 1 or 2 feet. The clayey subsoil renders the soil retentive of moisture. The soil is in places highly calcareous. One sample of the surface soil contained 6·46 per cent of lime and the subsoil 10·86 per cent. The content of organic matter is generally higher than in the sandier soils.

The surface is nearly level or gently sloping and in places the natural drainage is somewhat deficient.

*Mechanical Analyses of Lacustrine Sandy Loam*

| Soil | Fine gravel 2 to 1 mm. | Coarse sand 1 to 0·5 mm. | Medium sand 0·5 to 0·25 mm. | Fine sand 0·25 to 0·1 mm. | Very fine sand 0·1 to 0·05 mm. | Silt 0·05 to 0·005 mm. | Clay 0·005– mm. |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % |
| Surface soil........... | 2·1 | 6·6 | 6·7 | 21·4 | 17·9 | 27·0 | 18·3 |
| Subsoil............... | 0·5 | 1·0 | 1·6 | 6·6 | 27·6 | 33·5 | 29·2 |

*Clay Loam and Clay.* The surface soil of the lacustrine clay loam and clay consists of brown to black clay loam or clay generally free from stones or boulders. The subsoil consists of yellowish or grey clay. The surface soil varies between a clay loam and clay and is one of the heaviest soils of the area, but is generally well supplied with organic matter and hence is not difficult to work. A sample of the surface soil was found to contain 1·31 per cent of lime and the subsoil 5·61 per cent.

The surface is nearly level or gently sloping and in places the natural drainage is deficient. The soils occupy comparatively small areas at the surface, but underlie a considerable part of the peat bogs in the north.

*Mechanical Analyses of Lacustrine Clay*

| Soil | Fine gravel 2 to 1 mm. | Coarse sand 1 to 0·05 mm. | Medium sand 0·5 to 0·25 mm. | Fine sand 0·25 to 0·1 mm. | Very fine sand 0·1 to 0·05 mm. | Silt 0·05 to 0·005 mm. | Clay 0·005– mm. |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % |
| Surface soil........... | 0·5 | 2·7 | 3·3 | 2·8 | 6·7 | 32·0 | 52·0 |
| Subsoil............... | 0·0 | 1·9 | 2·5 | 8·0 | 13·9 | 37·7 | 36·0 |

### *Glacial Till Soils*

*Fine Sandy Loam.* The surface soil for the most part consists of yellowish brown to black, fine, sandy loam containing varying amounts of gravel, stones, and boulders. The subsoil consists of yellowish clay loam or clay containing stones and boulders. In places the soil is nearly free from stones and is markedly clayey. In other places it is more sandy and is stony. A sample of the surface soil contained 0·4 per cent of lime and the subsoil 13·71 per cent. The soil is mostly well supplied with organic matter and is highly productive where it is not too stony.

The areas occur chiefly in the southwest, but occupy a considerable part of the whole. The surface for the most part is slightly rolling or sloping. In places low ridges or irregularly-shaped hills occur, but the relief is generally low. The surface as a whole is naturally drained.

*Mechanical Analyses of Fine Sandy Loam*

| Soil | Fine gravel 2 to 1 mm. | Coarse sand 1 to 0·05 mm. | Medium sand 0·5 to 0·25 mm. | Fine sand 0·25 to 0·01 mm. | Very fine sand 0·5 to 0·05 mm. | Silt 0·05 to 0·005 mm. | Clay 0·005– mm. |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % |
| Surface soil........ | 4·3 | 6·2 | 9·6 | 21·5 | 31·3 | 19·3 | 4·8 |
| Subsoil.. .......... | 2·5 | 5·0 | 6·5 | 16·4 | 30·3 | 27·0 | 12·3 |

*Stony Loam.* The soil consists of brown to black loam or sandy loam containing considerable quantities of stones and boulders. The areas are too stony for agriculture, but are suitable for grazing and are best adapted for the forest growth.

*Fine Sand and Sandy Loam.* The surface soil consists of light-coloured. fine sand or sandy loam containing varying amounts of gravel, stones, and boulders. The subsoil consists of yellowish, sandy loam or fine, sandy loam containing in places stones and boulders. The areas occur chiefly in the highland, southwestern part of the district and have in places a marked local relief. Numerous irregularly-shaped hills and undrained basins, which, however, because of the porous character of the soil and the general relief of the area usually contain no water, occur in the highland areas. The areas are clothed chiefly with jackpine. The water-level in the highland areas occupied by these soils is generally at a considerable distance from the surface and the soils are deficient in organic matter. They are, therefore, better suited for forest growth than for agriculture.

## BRICK-CLAYS

Clay suitable for making bricks occurs in the lacustrine clays, which are, however, only rarely exposed. It occurs in the valley of Sprague creek; in the lower part of the Whitemouth valley, and near Hadashville. It also occurs beneath the peat at numerous places in the north. Sections exposed in the construction of the aqueduct showed 15 to 20 feet of brick-clay on the summit level where it is overlain by 6 to 10 feet of peat. It is yellow and calcareous, and is in places underlain by a highly plastic and sticky, bluish-grey clay. The underclay because of its tendency to crack badly and shrink in drying is not suitable for making bricks.

Several samples of the yellow, upper clays from Sprague were tested in the laboratories of the Department of Mines. Regarding the results of the tests Mr. Keele states, "These clays will make very good buff-coloured building brick by the soft-mud process, and it is possible that hollow brick or drain tile can be made by the stiff-mud machine. The drying is their weak point, but by slow drying and protection from hot winds, they can be dried[1] intact. In order to secure a hard, durable product, the burning must be carried to the temperature of cone 1 or nearly so. The clay contains enough small lime particles to cause underburned wares made from it to disintegrate; hence it is an unsafe material to use unless

[1]Geol. Surv., Can., Mem. 65, pt. V, 1915, p. 2.

fully burned. These clays, in general, are similar to those worked for brickmaking at Morris, Winnipeg, and Balmoral and are representative of the brick clays of the Red River valley, in Manitoba, as described in Memoir 24."

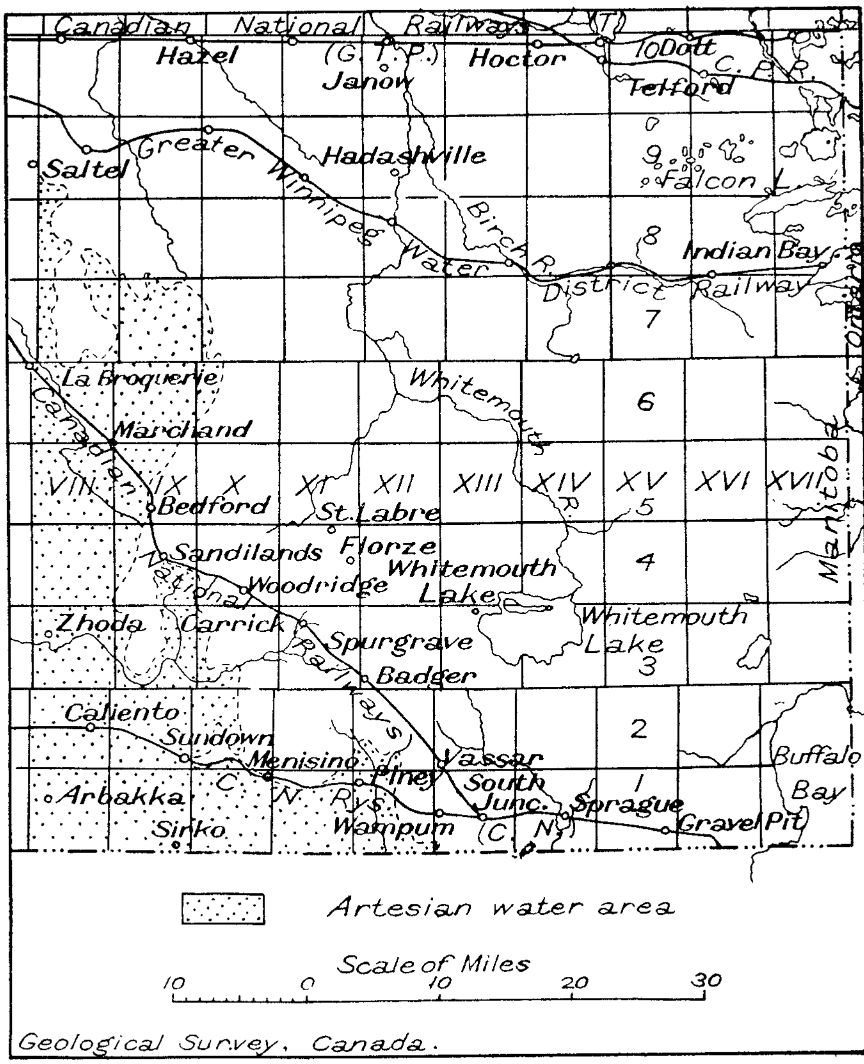


Figure 2. Diagram showing artesian-water area, Upper Whitemouth River area, southeastern Manitoba.

## SANDS AND GRAVELS

Sands and gravels useful for structural purposes, for road material, and for ballast, occur at many places in the district chiefly in the form of ancient littoral or beach deposits. The localities where the beach sands and gravels occur are shown on the accompanying map (No. 1802). A single deposit of fluvioglacial gravels, in which a government gravel pit is located, occurs northeast of Birch river. The beach deposits as a rule contain more sand than gravel, and this renders much of the material of poor quality for road metal unless it is screened. Much of the gravel is limestone which crushes easily and is soluble to some extent in rain water so that it is not very durable. The beach deposits vary from 10 to 15 feet in thickness and 100 to 500 feet in width and extend for considerable distances. The sands and gravels exposed at the surface are nearly all calcareous.

## WATER SUPPLY

The groundwater-level is practically at the surface in the swampy areas, and except in the highland drift area is within a few feet of the surface throughout the remainder of the area. There is, therefore, little difficulty in securing water for domestic purposes by means of wells. In places, however, in the highland area, wells have been sunk to a depth of 50 feet or even more before obtaining water. The swamp waters of most of the area are remarkably clear and potable because of the abundance of limestone which causes the fine organic matter in suspension to flocculate (or gather into bunches) and settle to the bottom. In the northeast where the limestone drift is absent the swamp water is coffee-coloured because of organic matter in suspension and is unfit for use.

Springs occur abundantly around the base of the highland drift area, but are not frequent elsewhere.

An artesian water area occurs in the southwest and west. Its extent is shown in Figure 2. Flowing wells are obtained by drilling to various depths of 50 to 200 feet in the drift deposits, very few of the wells reaching bedrock. They have been obtained at La Broquerie; in Pine Creek valley; and at other places. In Pine Creek valley the water rises to about 1,110 feet above the sea or 50 feet above lake of the Woods. The water is obtained in the sands and gravels underlying the upper till sheet, which acts as a nearly impervious cover; the source or collecting ground of the water is the highland area, which rises in places to 1,310 feet above the sea. Much of the drift material in the highland area is sand and gravel through which the water supplied by rainfall passes downward and flows in the gravel deposits beneath the upper till sheet, westward and southwestward down the slope towards Red River valley.

No waterpowers occur in the area.

# INDEX

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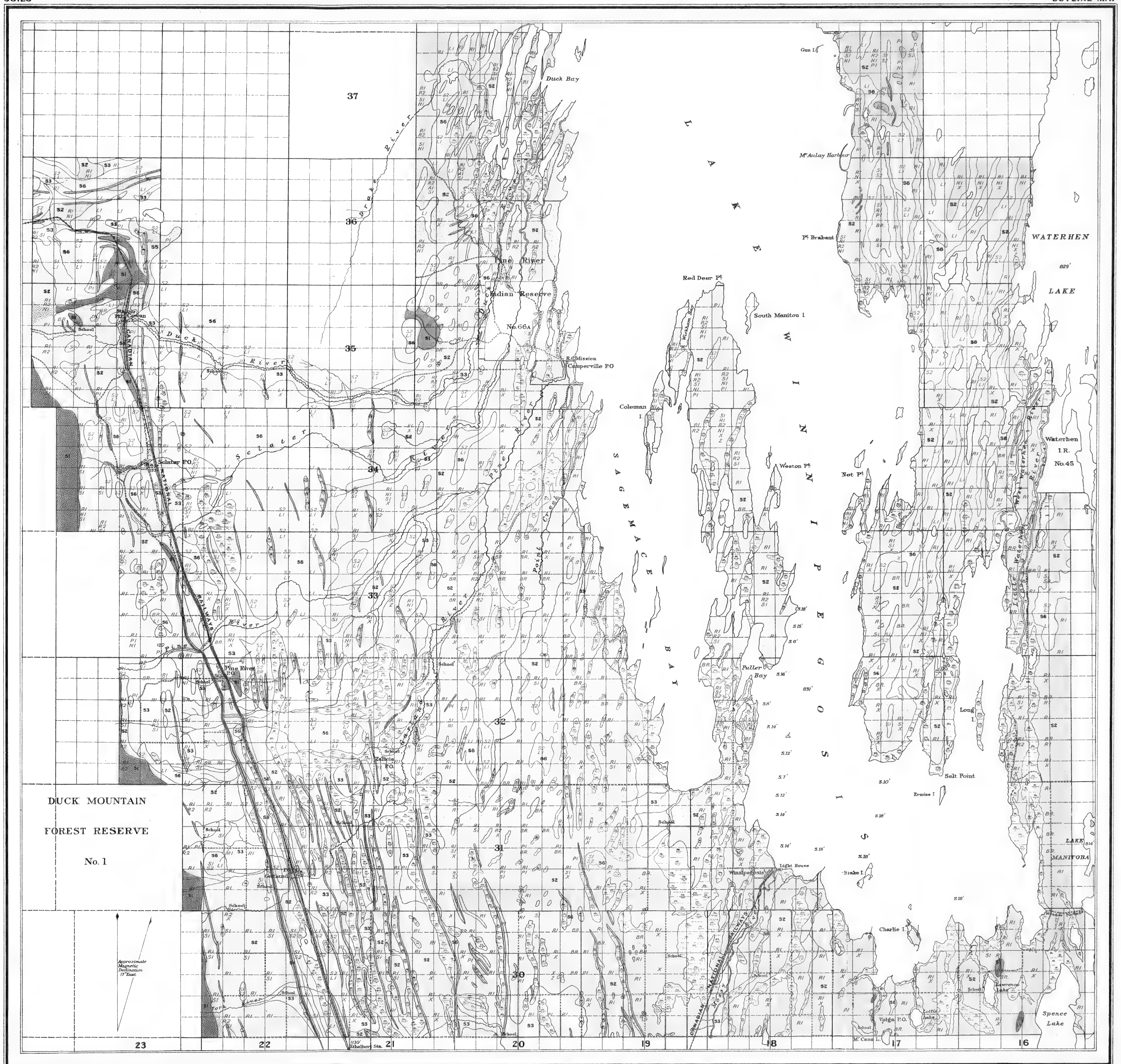
Canada
Department of Mines

HON. SIR JAMES A. LOUGHEED, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR.

SOILS | Issued 1921 | OUTLINE MAP




C. O. Senécal, Geographer and Chief Draughtsman
J. O. Fortin, Draughtsman

Publication No. 1771

## WINNIPEGOSIS; TOWNSHIPS 30 TO 37, RANGES 16 TO 23, WEST OF PRINCIPAL MERIDIAN, MANITOBA

Scale of Miles

Geology by W. A. Johnston, 1917-1918.

To accompany Memoir by W. A. Johnston

## LEGEND

QUATERNARY

| | Unconsolidated rocks upon which the soils are developed | Soils |
|---|---|---|
| RECENT | Muck and peat *(swamp and pond deposits)* | S6 Muck and peat *(1 foot or more in thickness)* |
| | Dune sand *(aeolian deposits)* | S5 Dune sand *(chiefly fine sand of little agricultural value)* |
| PLEISTOCENE | Beach sand and gravel *(littoral deposits of glacial Lake Agassiz)* | S4 Gravelly sand and coarse sand *(soil, for the most part deficient in organic matter and easily affected by drought; surface in the form of low ridges)* |
| | Lacustrine sand and silt *(stratified delta and lake-bed deposits of glacial Lake Agassiz, including some alluvial, flood-plain deposits)* | S3 Fine sand and sandy loam *(soil, for the most part good but in places poorly drained; surface nearly level or gently sloping)* |
| | Glacial boulder clay | S2 Clay loam and clay *(soil good but stony in places; surface undulating and for the most part naturally drained)* |
| | | S1 Stony loam *(soil, for the most part too stony for agricultural purposes except for grazing; surface undulating)* |

Bedrock outcrop *(limestone)*

### Symbols

Terminal morainic area

Hay marsh

Glacial striæ

Soil boundary *(approximate)*

1202′ Figures *showing elevations in feet above sea-level*

S15′ Soundings

Diagram
Showing Subdivision of Townships

| | | | | | |
|---|---|---|---|---|---|
| 31 | 32 | 33 | 34 | 35 | 36 |
| 30 | 29 | 28 | 27 | 26 | 25 |
| 19 | 20 | 21 | 22 | 23 | 24 |
| 18 | 17 | 16 | 15 | 14 | 13 |
| 7 | 8 | 9 | 10 | 11 | 12 |
| 6 | 5 | 4 | 3 | 2 | 1 |

### Forest cover

- P1 Pinus Banksiana ........ Jack pine
- A1 Abies balsamea ........ Balsam fir
- S1 Picea canadensis ........ White spruce
- S2 Picea mariana ........ Black spruce
- L1 Larix laricina ........ Tamarack
- R1 Populus tremuloides ........ Aspen poplar
- R2 Populus balsamifera ........ Balsam poplar
- N1 Betula papyrifera ........ Paper birch
- Z Alnus ........ Alder
- X Salix ........ Willow
- BR. ........ Brulé

# Canada
## Department of Mines

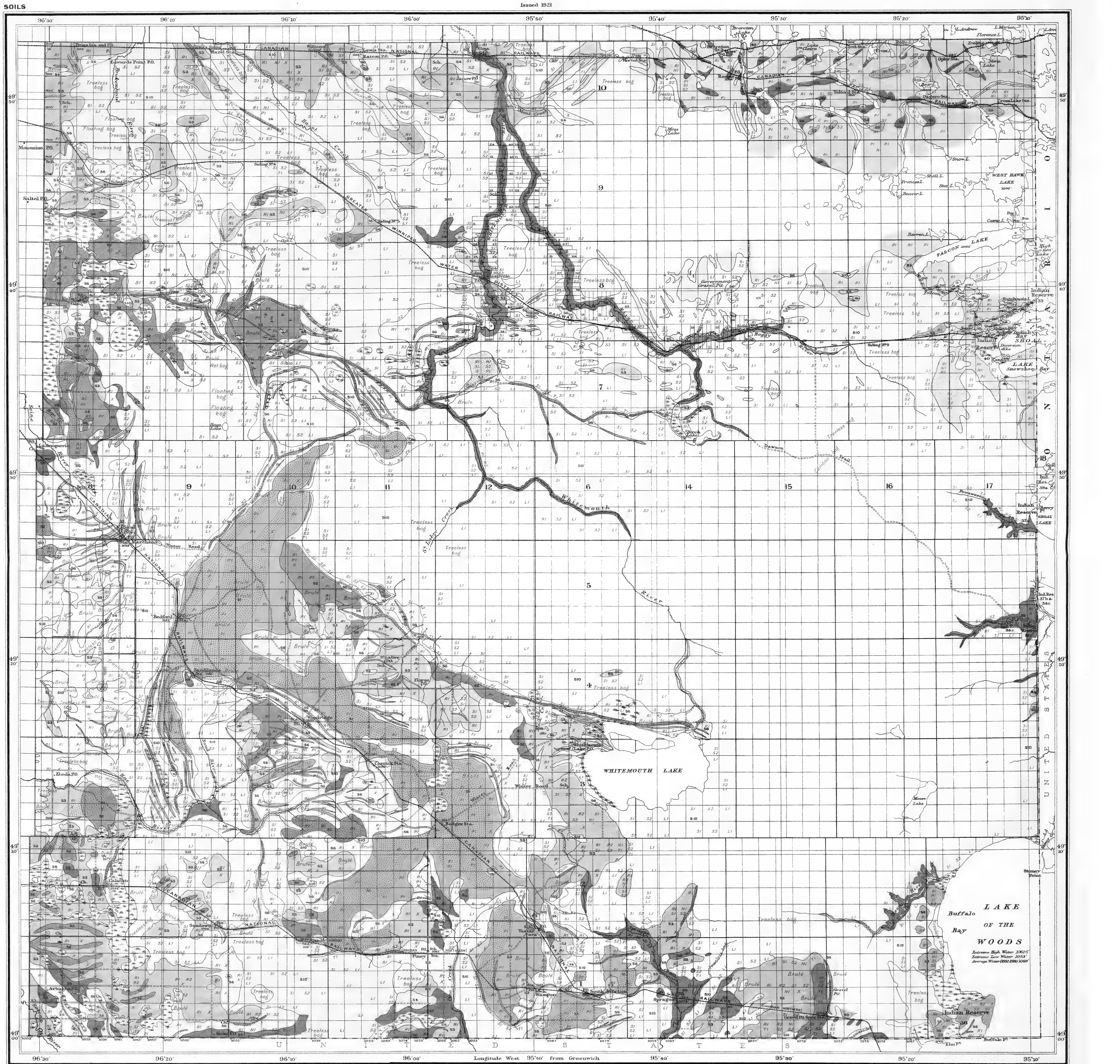
HON. SIR JAMES A. LOUGHEED, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY

W.H. COLLINS, DIRECTOR.

SOILS

Issued 1921




C.O. Senécal, Geographer and Chief Draughtsman.
A. Braidwood, Draughtsman.

Publication Nº 1802

## LEGEND

**Unconsolidated Rocks**
*upon which soils are developed*

**Soils**

QUATERNARY

RECENT

Muck and peat — *swamp and pond deposits*

S10 — **Muck and peat** — *1 foot or more in depth. The swamp deposits are generally only from 1 to 3 feet deep, except in the central parts of swamps and in treeless bogs; large areas can be drained and converted into agricultural land.*

Dune-sand — *aeolian deposits*

S9 — **Dune-sand** — *soil of little agricultural value.*

Alluvial sand and silt — *flood-plain deposits of present streams.*

S8 — **Fine sand and sandy loam** — *soil highly productive; areas subject to overflow.*

PLEISTOCENE

Beach-sand and gravel — *littoral deposits of glacial Lake Agassiz.*

S7 — **Gravelly sand and coarse sand** — *soil, in most places deficient in organic matter and easily affected by drought; surface in the form of low ridges.*

Lacustrine sand, silt and clay — *stratified valley-fill, delta and lake-bed deposits of glacial Lake Agassiz; includes some alluvial, flood-plain deposits.*

S6 — **Fine sand and sandy loam** — *soil in places deficient in organic matter; not easily affected by drought because of nearness to surface of ground water level; surface nearly level or gently sloping.*

S5 — **Sandy loam** — *(clay loam subsoil) soil good; surface nearly level or gently sloping.*

S4 — **Clay loam and clay** — *(clay subsoil) soil good but in places poorly drained; surface nearly level or gently sloping.*

Glacial till or boulder clay and outwash sand and gravel — *unstratified and, in small part stratified deposits of ice-sheets, Wisconsin stage of glaciation.*

S3 — **Fine sandy loam** — *(clay loam subsoil) soil good but stony in places; surface undulating.*

S2 — **Stony loam** — *soil, for the most part too stony for agricultural purposes except for grazing; surface undulating or hilly.*

S1 — **Fine sand and sandy loam** — *soil deficient in organic matter and easily affected by drought; surface undulating or hilly.*

**Bedrock outcrop** — *(little or no soil covering) areas of low agricultural value; better adapted for forest cultivation.*

### Symbols

**Terminal morainic areas** — *surface undulating or hilly.*

**Hay marsh**

**Glacial striae**

**Soil boundary** — *approximate*

1036′ — **Figures** — *showing elevations in feet above sea-level*

**Note**

*Clay suitable for making bricks occurs in the lacustrine clay and clay loam; sand and gravel for road material, ballast and structural purposes in the beach sand and lacustrine fine sand; peat for fuel in the deep bogs.*

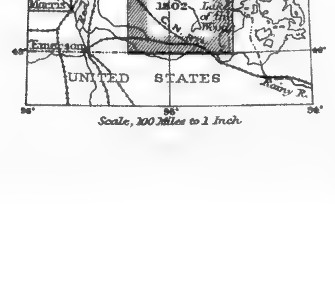
**Diagram**
Shewing Subdivision of Townships

| | | | | | |
|---|---|---|---|---|---|
| 31 | 32 | 33 | 34 | 35 | 36 |
| 30 | 29 | 28 | 27 | 26 | 25 |
| 19 | 20 | 21 | 22 | 23 | 24 |
| 18 | 17 | 16 | 15 | 14 | 13 |
| 7 | 8 | 9 | 10 | 11 | 12 |
| 6 | 5 | 4 | 3 | 2 | 1 |

### Forest Cover

| | | |
|---|---|---|
| P1 | Pinus Banksiana | Jack Pine |
| S1 | Picea canadensis | White Spruce |
| S2 | Picea mariana | Black Spruce |
| T1 | Thuja occidentalis | Cedar |
| L1 | Larix laricina | Tamarack |
| R1 | Populus tremuloides | Aspen Poplar |
| R2 | Populus balsamifera | Balsam Poplar |
| N1 | Betula papyrifera | Paper Birch |
| M1 | Acer Negundo | Manitoba Maple |
| F1 | Fraxinus pennsylvanica | Green Ash |
| E1 | Ulmus americana | White Elm |
| Z | Alnus | Alder |
| X | Salix | Willow |

*To accompany Memoir by W.A. Johnston.*




# UPPER WHITEMOUTH RIVER

*(TOWNSHIPS 1 TO 10, RANGES 8 TO 18, EAST OF PRINCIPAL MERIDIAN)*

**MANITOBA**

Scale, $\frac{1}{190,080}$

Miles: 2 1 0 2 4 6 8 10

Kilometres: 2 0 2 4 6 8 10 12

3 MILES TO 1 INCH

GEOLOGY

W.A. JOHNSTON 1916